Scottish Sanitary Survey Programme

Sanitary Survey Report
Production Area: Loch Roag: Miavaig

SIN: LH 188 123 08

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Cefas

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Report Distribution – Loch Roag: Miavaig

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I. Executive Summary

A sanitary survey has been undertaken at Loch Roag: Maivaig due to its proximity with the survey of the neighbouring production area Loch Roag: Eilean Teinish.

Loch Roag is a remote complex of lochs and small islands on the west coast of the Isle of Lewis, in the Outer Hebrides. It lies approximately 35 km west of the island capital, Stornoway. The loch supports a significant number of shellfish and salmon farms. Miavaig is located in the western end of the loch. The surrounding area is rugged and sparsely populated, with small settlements along the north shoreline. There is a seasonal influx of visitors, and tour and pleasure boats operate in the loch.

The Loch Roag: Miavaig shellfish farm consists of 5 double headed longlines oriented approximately north-south, located to the east of Aird Meinish, just outside Loch Miavaig in Loch Roag. Droppers nearest the shore extend to 6 metres depth and all others to 8 metres. Harvest may occur at any time of year, in accordance with market demand.

There is no mains sewerage provision for properties adjacent to Loch Miabhaig or Miavaig Bay. The majority of dwellings have private septic tanks discharging to soakaway systems in areas of freely draining soils. Some of the septic tanks around Loch Miabhaig, Riof and along the road north of Cairisiadar discharge either to the streams or directly to the waters of the loch and these are likely to affect water quality in the near vicinity. A church at the head of the loch and facilities at Miavaig pier are likely to contribute the largest discharges in terms of volume. An outfall pipe located 720 metres west of the mussel farm and two streams located 300 metres and 450 metres east of the mussel farm all were found to contain *E. coli* concentrations suggestive of septic input.

Diffuse agricultural pollution from livestock that are grazed throughout the area is also likely to be a significant contributor to faecal contamination at the fishery. The largest concentrations of animals were found at Riof and on land west of the fishery. The numbers of livestock animals grazed in the area is likely to be higher in summer, when lambs are present.

During periods of heavy rain, runoff from land is likely to wash faecal material into the loch and any impact on the fishery is most likely to affect the lines nearest the shore.

Wildlife species in and around Loch Roag are likely to contribute to background levels of contamination in waters at the fishery, with relatively small numbers of animals likely to be present. Waterfowl may directly deposit droppings at or near the mussel lines: impacts from this source are likely to be higher nearer the surface.

Currents are weak in the overall area, and faecal contamination arising from land adjacent to the fishery is expected to have the greatest impact on water

quality at the mussel farm. On the ebb tide, the north-west corner of the lines will be exposed to contamination arising from the vicinity of Uigean. The watercourses on the outer northern shore, including the Riof area, will potentially impact on the northern part of the lines. Considering the predicted movement of contaminants, sources closest to the fishery are more likely to have an effect and therefore the northeastern end of the mussel farm may be most affected. The south-west corner of the lines may be exposed to contamination coming out of Loch Miavaig.

Significant correlations were found between monitoring results and both rainfall and the high/low tidal cycle.

There appears to have been no change in the underlying level of *E. coli* contamination in the fishery over the past five years. A tendency towards lower results in the first part of the year was seen, with the highest results usually occurring between August and November. Geographic variation in results was apparent, with higher results were seen in a band across the eastern side of the mussel farm, along a line from Eilean Aird Meithinis to Rubh' a' Scarp. Overall levels of faecal contamination in this area are relatively low, with 10 results greater than 230 *E. coli* MPN/100g (18%) recorded from 2007-2011, and no results greater than 4600 *E. coli* MPN/100g during the same period.

Recommendations

It is recommended that the production area be amended to exclude potential sources of faecal contamination and to include the entire recorded mussel line area plus a small buffer for movement of the lines. Although there are livestock along the shoreline immediately north and west of the fishery, the Crown Estate lease for the mussel farm extends to the shore and so the production area is extended to MHWS along this boundary.

The recommended boundaries are described as the area bounded by lines drawn between NB 0957 3400 and NB 0956 3350 and between NB 0956 3350 and NB 1029 3367 and between NB 1029 3367 and NB 1042 3437 and extending to MHWS.

It is recommended that the RMP be relocated to NB 1028 3424 to reflect the larger sources of contamination to the east at Riof. This is also in the line across the fishery where historical samples have yielded the highest results.

II. Sampling Plan

PRODUCTION AREA	Loch Roag: Miavaig
SITE NAME	Miavaig
SIN	LH 188 123 08
SPECIES	Common mussels
TYPE OF FISHERY	Long-line aquaculture
NGR OF RMP	NB 1028 3424
EAST	110280
NORTH	934240
TOLERANCE (M)	40
DEPTH (M)	1-3
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Comhairle nan Eilean Siar
AUTHORISED SAMPLER(S)	Paul Tyler
LOCAL AUTHORITY LIAISON OFFICER	

III. Report

1. General Description

Loch Roag is a remote complex of lochs and small islands on the western coast of the Isle of Lewis. Its shores are sparsely populated and the loch supports a significant number of shellfish and salmon farms. It is 7 km long and has a maximum depth of 40 m, though at the production area examined for this report it is 0 - 18 metres in depth. Miavaig is located in the western end of the loch.

The survey was conducted due to its proximity and resulting agglomeration with the survey of the neighbouring site Eilean Teinish. However, due to the differences in proximity to contaminating sources and probable movement of contaminants, it was agreed with the Food Standards Agency Scotland that these be addressed in separate reports.

Figure 1.1 Location of Loch Roag Miavaig

2. Fishery

The Loch Roag: Miavaig shellfish farm consists of 5 double headed longlines orientated roughly North-South to the east of Aird Meinish, just outside Loch Miabhaig in Miavaig Bay. Droppers nearest the shore extend to 6 meters depth and all others to 8 meters. Harvest may occur at any time of year, in accordance with market demand.

The current production area boundary is defined by lines drawn between NB 1000 3327 and NB 1040 3438 extending to MHWS. The nominal Representative Monitoring Point (RMP) is reported at NB 0989 3423.

The actual location of the mussel farm within the loch was recorded during the shoreline survey and is shown together with the current production area boundaries, RMP and lease areas in Figure 2.1.

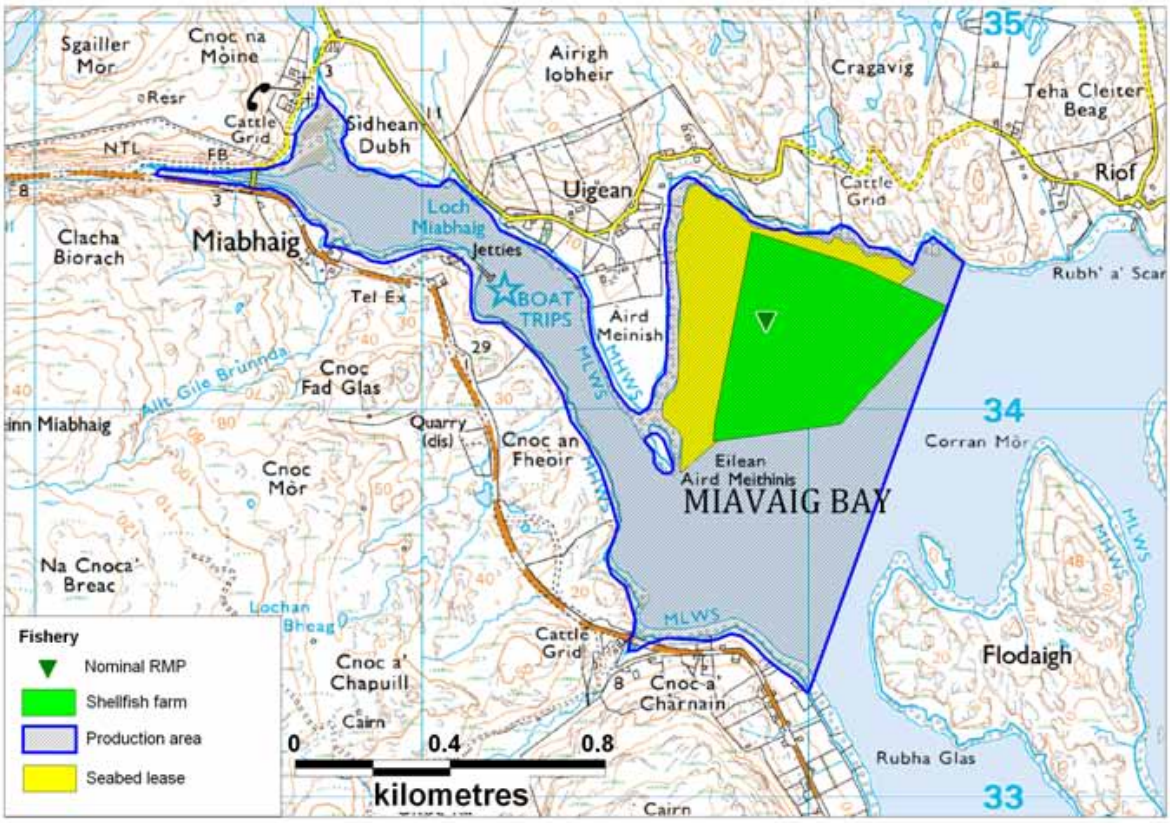

Figure 2.1 Loch Roag: Miavaig Fishery

3. Human Population

Information on the human population of the area around Loch Roag: Miavaig was obtained from the General Register Office for Scotland. Data was provided for the 2001 census by output area. The population density for the output areas nearest the fishery is shown thematically mapped in Figure 3.1.

Figure 3.1 Population map of Loch Roag: Miavaig

The population density is low for the areas surrounding the western shore of Loch Roag. There are three small settlements; Miavaig at the head of Loch Miabhaig, Uigean and Riof on the northern shore of Loch Miabhaig/Miavaig Bay. The remainder of dwellings are found located along the road running along either side of Loch Miabhaig and south toward Cairisiadar. The settlement of Geisiadar lies further to the southeast and outside the boundary of the map in Figure 3.1.

The population in the surrounding area is spread amongst three census output areas. The population for each census area is listed in Table 3.1.

Table 3.1 Census output areas: Loch Roag: Miavaig

Output area	Population
60RJ000064	131
60RJ000065	74
60RJ000062	62
Total	**267**

There is a small pier half way along the southern shoreline of Loch Miabhaig where a local wildlife boat tour operates from. The wildlife tour operator has one boat with seating for 10 people and two RIBs, with trips running from April to October. During the shoreline survey it was observed that pleasure boats and fishing boats were also moored at the pier. On the day of the survey, there were 16 small boats and 3 larger fishing boats present, and 8 empty moorings. There is also an anchorage located to the east of the pier. It was noted a number of the homes in the area are in seasonal occupation, either as holiday homes or self-catering rentals. Although no hotels or campsites were observed along the shore of the fishery, there is a large campsite adjacent to a beach northwest of Riof, outside the loch. This has a toilet and shower block, though no discharge to sea was observed during the shoreline survey undertaken for Loch Roag: Eilean Teinish.

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified no public sewerage discharges to the waters of Loch Miabhaig or the western reaches of Loch Roag.

SEPA provided information on a number of consented discharges, which are listed in Table 4.2. No information was provided regarding the consented flow or design Population Equivalent (PE) of these discharges. The majority appear to serve single homes and therefore each discharge would carry relatively very small volumes of sewage. Most of the consents are for discharge to either soakaway or to land, however 13 discharge to watercourses or to sea. Two consents pertain to marine cage fish farms, the effluent from which would not be expected to contain significant amounts of faecal indicator bacteria or human pathogens. However, discharges from any toilet facilities on service barges associated with the fish farms would be expected to contribute human faecal waste to the waters in their vicinity.

Table 4.1 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Discharges to
1	CAR/R/1059644	NB 08210 35860	Sewage	Primary	Land
2	CAR/R/1059640	NB 08266 35814	Sewage	Primary	Soakaway
3	CAR/R/1028977	NB 08290 35720	Sewage	Primary	Soakaway
4	CAR/R/1059743	NB 08724 34928	Sewage	Primary	Unnamed watercourse
5	CAR/R/1050154	NB 08742 34825	Sewage	Primary	Loch Miabhaig
6	CAR/R/1065121	NB 08720 34800	Sewage	Primary	Loch Miabhaig
7	CAR/R/1046590	NB 08759 34337	Sewage	Primary	Land
8	CAR/R/1050208	NB 08810 34430	Sewage	Primary	Loch Miabhaig
9	CAR/R/1056394	NB 09080 34360	Sewage	Primary	Soakaway
10	CAR/R/1064958	NB 09417 34313	Sewage	Primary	Loch Miabhaig
11	CAR/R/1041205	NB 09354 34507	Sewage	Primary	Soakaway
12	CAR/R/1057447	NB 09367 34499	Sewage	Primary	Soakaway
13	CAR/R/1057451	NB 09400 34510	Sewage	Primary	Soakaway
14	CAR/R/1056401	NB 09511 34444	Sewage	Primary	Soakaway
15	CAR/R/1056400	NB 09507 34442	Sewage	Primary	Soakaway
16	CAR/R/1056466	NB 09515 34446	Sewage	Primary	Land
17	CAR/R/1077622	NB 09650 34638	Sewage	Primary	Soakaway
18	CAR/R/1078467	NB 09675 34701	Sewage	Primary	Soakaway
19	CAR/R/1047647	NB 10500 34750	Sewage	Primary	Soakaway
20	CAR/R/1016095	NB 10540 34730	Sewage	Primary	Land
21	CAR/R/1041209	NB 10509 34655	Sewage	Primary	Soakaway
22	CAR/R/1047232	NB 10560 34550	Sewage	Primary	Soakaway
23	CAR/R/1066368	NB 10624 34521	Sewage	Primary	U/T of Loch Roag
24	CAR/R/1062064	NB 10680 34600	Sewage	Primary	Land
25	CAR/R/1054904	NB 10803 34522	Sewage	Primary	Soakaway
26	CAR/R/1054897	NB 10821 34517	Sewage	Primary	Loch Roag
27	CAR/R/1038779	NB 10840 34460	Sewage	Primary	Loch Roag
27	CAR/R/1047163	NB 09945 33322	Sewage	Primary	Loch Roag
28	CAR/R/1048511	NB 10964 34446	Sewage	Primary	Loch Roag
29	CAR/R/1043318	NB 11087 34475	Sewage	Primary	Soakaway
30	CAR/R/1041208	NB 11090 34665	Sewage	Primary	Soakaway

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Discharges to
31	CAR/R/1061947	NB 11099 34664	Sewage	Primary	Soakaway
32	CAR/R/1043395	NB 11358 34611	Sewage	Primary	Soakaway
33	CAR/R/1041207	NB 11373 34501	Sewage	Primary	Soakaway
34	CAR/R/1068118	NB 09531 33375	Sewage	Primary	Abhainn Uasaig
35	CAR/R/1068496	NB 09680 33380	Sewage	Primary	Loch Roag
36	CAR/R/1050563	NB 09830 33430	Sewage	Primary	Loch Roag
38	CAR/R/1080554	NB 09930 33150	Sewage	Primary	Soakaway
39	CAR/R/1059716	NB 09977 33036	Sewage	Primary	Soakaway
40	CAR/R/1075831	NB 10060 32930	Sewage	Primary	Soakaway
41	CAR/R/1061913	NB 10140 32920	Sewage	Primary	Soakaway
42	CAR/R/1049120	NB 10150 32790	Sewage	Primary	Loch Roag
43	CAR/R/1056459	NB 10165 32549	Sewage	Primary	Abhainn Mhor a Ghlinne Ruaidh
44	CAR/R/1063383	NB 10264 32166	Sewage	Primary	Abhainn Mhor a Ghlinne Ruaidh
45	CAR/R/1047646	NB 10272 32143	Sewage	Primary	Abhainn Mhor a Ghlinne Ruaidh
46	CAR/R/1057456	NB 11400 32200	Sewage	Primary	Tob Grasabhaig
47	CAR/R/1068150	NB 11480 32090	Sewage	Primary	Soakaway
48	CAR/R/1059468	NB 11665 31859	Sewage	Primary	Soakaway
49	CAR/R/1061863	NB 11815 31658	Sewage	Primary	Soakaway
50	CAR/R/1042013	NB 11760 31520	Sewage	Secondary	Soakaway
51	CAR/R/1056250	NB 11397 31446	Sewage	Primary	U/T of Loch Geisiadar
52	CAR/R/1059982	NB 11396 31303	Sewage	Primary	Loch Geisiadair
54	CAR/L/1002929	NB 11100 33800	Marine cage fish farm	-	-
55	CAR/L/1015852	NB 12100 33100	Marine cage fish farm	-	-

Sewage infrastructure and other potential sources of human septic waste recorded during the shoreline survey is listed in Table 4.3.

Table 4.2 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	18/07/2011	NB 11086 34395	House, presumed to be on septic tank. No pipe to shore evident.
2	18/07/2011	NB 11061 34594	Concrete septic tank with small diameter pipe overflow to land/ditch - not flowing
3	18/07/2011	NB 10864 34454	End of ceramic pipe, no apparent flow - no sewage fungus, though a strip of bright green algae on seabed
4	18/07/2011	NB 10859 34473	Septic tank, discharge pipe leading downward, but no outfall pipe visible from shore
5	18/07/2011	NB 10829 34523	House with septic tank on shore side of road
6	18/07/2011	NB 10670 34382	Stream below houses, water sample result 7200 *E.coli* cfu/100 ml.
7	18/07/2011	NB 09196 34483	Rock on ST cover downhill from road.
8	18/07/2011	NB 09422 34313	Iron pipe sticking up from ground. Foul odour in air
9	18/07/2011	NB 09414 34316	Ceramic septic pipe, appears to be connected, runs under shore, no outlet found. Seawater sample taken offshore of pipe result 1400 *E.coli* cfu/100 ml
10	18/07/2011	NB 09398 34331	Sewage fungus on shore
11	18/07/2011	NB 09342 34370	1 yacht plus 4 open boats on moorings, angling and fishing, small boats at pier

No.	Date	NGR	Description
12	18/07/2011	NB 09288 34404	Land runoff and septic tank outfall
13	18/07/2011	NB 09196 34483	Foul odour
14	21/07/2011	NB 08730 34786	Old septic tank, outlet/overflow pipe dry and did not appear recently used
15	21/07/2011	NB 08732 34803	Discharge pipe below church. Very slight flow
16	21/07/2011	NB 08719 34871	Pipe running into culvert, end not visible, upstream of sample
17	21/07/2011	NB 08699 34812	Septic tank vent adjacent to house
18	21/07/2011	NB 08679 34735	Outfall pipe, iron, below house. No flow apparent
19	21/07/2011	NB 08794 34396	House at shoreline, no discharge pipes apparent
20	21/07/2011	NB 08943 34312	Building with septic tank draining to land
21	21/07/2011	NB 09079 34395	Septic tank outlet, not flowing
22	21/07/2011	NB 09124 34385	Miaviag pier, 16 small boats and 3 larger fishing boats (all under 15m). Diesel sheen and odour on water. Approx 8 empty moorings. Salmon site office, tourist boat operator shed.
23	21/07/2011	NB 09547 33385	Septic pipe dripping into pooled stream at road
24	21/07/2011	NB 09702 33385	Septic tank above shore, 12 sheep, no pipe or odour detected
25	21/07/2011	NB 09863 33375	Adjacent septic tanks (2) above shore, 2 pipes - 1 ceramic pipe runs to tide line, not flowing. 1 plastic pipe to top of bank, dripping
26	21/07/2011	NB 09938 33313	Cast iron discharge pipe with trickling land drainage adjacent. Pipe broken in places. Carpet of green algae
27	21/07/2011	NB 10159 32771	4 pipes draining to shore, none actively flowing, all appear to be septic pipes. Some green algae present
28	21/07/2011	NB 10097 32741	Septic tank near house, west side of road. East side of road - farm storage/animal housing

The observed septic tanks and outfalls in most cases appeared to correspond to consents provided by SEPA, as can be seen in Figure 4.1. In some cases, there appeared to be discharge pipes to shore adjacent to where septic tanks were identified as being on soakaway systems. The largest concentration of observed septic tanks was found around Loch Miabhaig, followed by Riof, and along the road north of Cairisiadar. Most of the tanks appear to be on soakaway systems. If appropriately sited and maintained in good working order, these should not materially impact water quality at the fishery. However, due to their proximity to the shore any overland flow resulting from failure of the soakaway field would be likely to impact the waters immediately adjacent. The septic tank from the church at the head of Loch Miabhaig (Table 4.1, No. 6 and Table 4.2, No. 15) is likely to discharge a significantly higher volume when the church is in use and will constitute a significant source to the head of the loch. None of the provided consents appeared to relate to the facilities at Miavaig Pier, and no discharge was observed from these buildings. However, toilets at the Marine Harvest base and tour boat base are likely to discharge somewhere in the area. A seawater sample taken at the slip way contained 63 *E. coli* cfu/100 ml, which is indicative of moderate faecal contamination. The source(s) of this contamination were not clear but may have included any discharge from the shore base, boats or other sources in the vicinity.

In addition to the discharges identified above, there is the potential for discharge to septic waste from boats as they pass the fishery on their way to or from moorings in Loch Miabhaig. Although larger commercial vessels are required to either treat sewage onboard or discharge from holding tanks to onshore waste facilities, these requirements do not apply to smaller vessels which are more likely to discharge overboard either from holding tanks or directly from marine heads. Should boats discharge as they pass the fishery, there is the potential for the sewage to impact the mussel farm, particularly along the southern boundary of the farm.

As there is no public sewerage provision in the area, what sewage does enter the loch is subject to limited treatment and therefore the impact to the fishery can actually be greater. The sources nearest the fishery are discharges at Riof (300 metres east of mussel farm), north of Cairisiadar (550 metres south of the mussel farm) and the north shore of Loch Miabhaig (580 metres west of the mussel farm). These may all impact different parts of the farm under different environmental conditions.

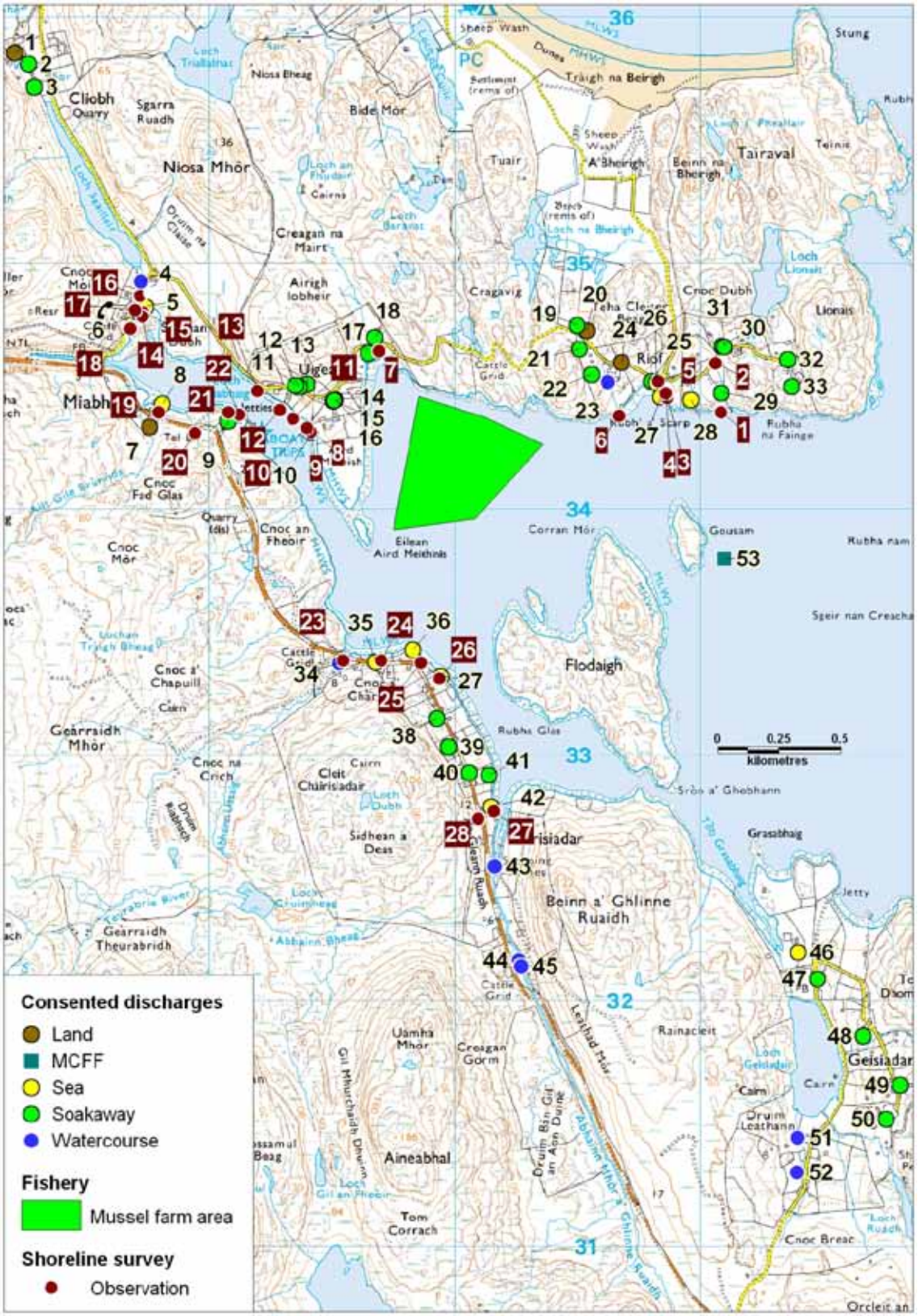

Figure 4.1 Map of discharges for Loch Roag: Miavaig

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 1. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

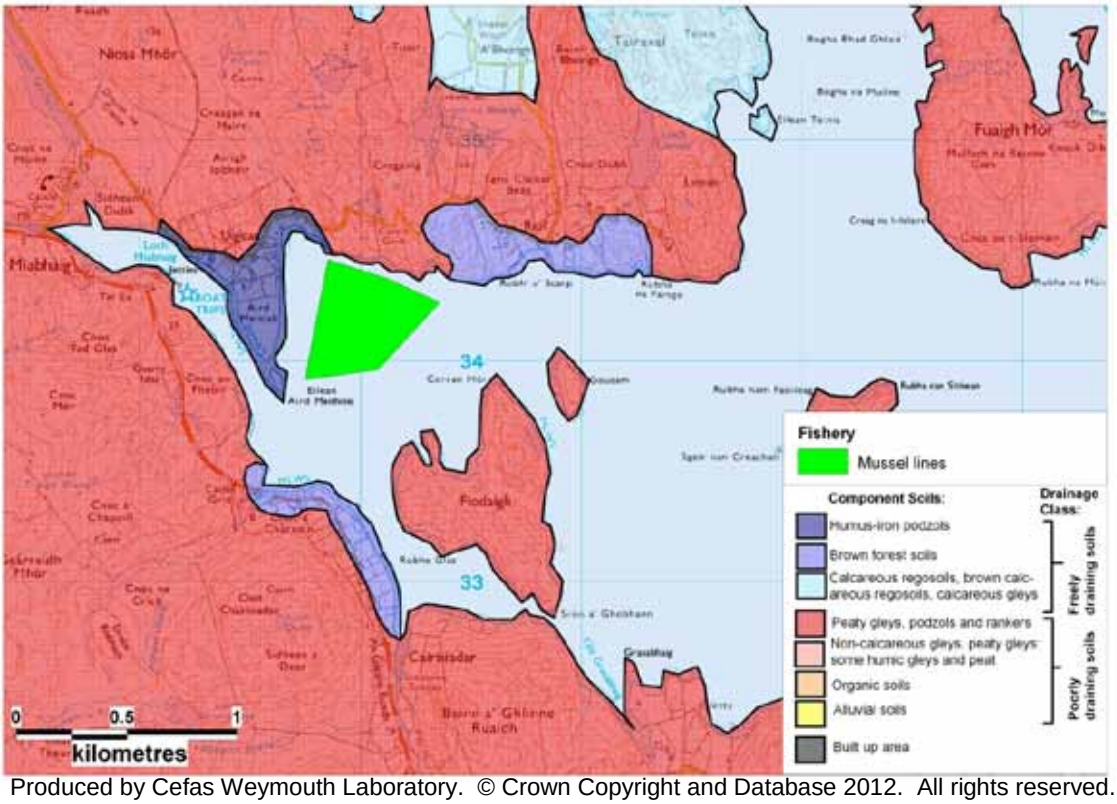

Figure 5.1 Component soils and drainage classes for Loch Roag: Miavaig

There are four types of soil found in this area. The most common is composed primarily of peaty gleys, podzols and rankers and covers the majority of the inland area, sections of the coastline including a large stretch of the Loch Miabhaig coastline and the shoreline north of the fishery and the majority of the islands offshore. The headland to the west of the fishery is composed of humus-iron podzols and an area of shoreline to the northeast and southwest of the fishery is composed of brown forest soils. Calcareous regosols, brown calcareous regosols and calcareous gleys are present inland from the neighbouring bay north of the fishery.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is therefore low for land immediately to the west at Uigean, along the shoreline at Riof to the north east, and along the shoreline stretching north from Cairisiadar, to the south of the fishery. All other areas have higher potential for contaminated runoff, and this may especially affect the northern extent of the fishery, where it most closely approaches an area of poor drainage.

6. Land Cover

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

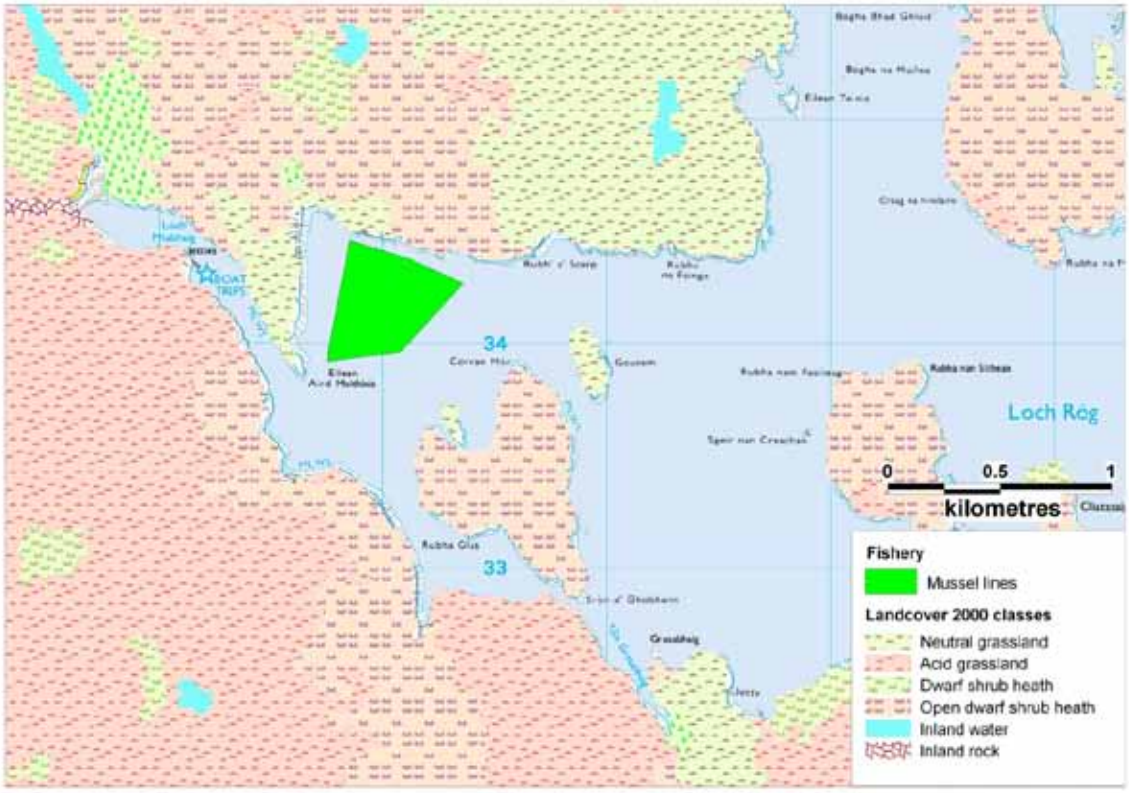

Figure 6.1 LCM2000 class land cover data for Loch Roag: Miavaig

The Landcover 2000 data indicates that there are four main land cover types found adjacent to the Loch Roag: Miavaig production area. The southern shore is primarily composed of acid grassland with an area of open dwarf shrub heath covering part of the shoreline continuing inland.

On the northern shore, adjacent to the shellfish farm, the land cover is a mix of heath and neutral grassland with small areas of improved grassland and other natural landcover types. A larger area of improved grassland is located on the north side of the head of Loch Miabhaig. There are no identified built up or urban areas.

During the shoreline survey it was observed that much of the grassland area was used for grazing livestock, and concentrations of animals were seen on areas of neutral and acid grassland (see Section 7). There were developed areas with hardstanding at the pier and at the head of Loch Miabhaig, which are not identified in the land cover data.

Studies undertaken by Kay et al (2008) found that faecal indicator organism export coefficients for faecal coliform bacteria were highest for urban catchment areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and rough grazing

(approximately $2.5x10^8$ cfu km^{-2} hr^{-1}) areas. Lowest contributions would be expected from areas of woodland (approximately $2.0x10^7$ cfu km^{-2} hr^{-1}). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

The potential for contaminated runoff attributable to land cover type is therefore highest around head of Loch Miabhaig, which also was identified in Section 5 as having poor soil drainage characteristics, which would enhance the likelihood of runoff. The potential for contamination from the grassland areas used for livestock grazing is moderate along the shores west, northwest and northeast of the fishery, and the risk for contamination from these areas is highest after rainfall.

Risk would be lowest from the areas of heathland, which is less likely to be grazed as intensively as the improved grassland. This lies to the north of the fishery as well as along the shore south of the fishery.

7. Farm Animals

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Uig parish. Reported livestock populations for the parish in 2009 and 2010 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock numbers in the Uig agricultural parish 2009 - 2010

	Uig 567 km^2			
	2009		2010	
	Holdings	Numbers	Holdings	Numbers
Pigs	10	27	10	33
Poultry	59	639	63	663
Cattle	52	345	64	400
Sheep	330	26517	303	23914
Horses used in Agriculture	*	*	*	*
Other horses and ponies	12	19	10	15

The parish area is large, extending approximately 30 km north to south and nearly the same east to west at its widest points. Sheep were the predominant livestock animals kept in the parish and outnumber the human population within the same area by over 15 to 1, based on 2001 human census data. However, the data above do not give a clear picture of the spatial distribution of animals within the parish.

Agricultural practices in Lewis were observed by Osgathorpe et al (2011) to consist predominantly of store lamb production on 'inbye' land – small, enclosed areas of lowland grass. They noted that no arable agriculture was carried out, and that the majority of crofters did not have access to upland grazing areas. This suggests that the majority of livestock within the Uig parish is likely to be kept on or very close to enclosed croft areas.

Observations of livestock, including tracks and droppings, taken during the shoreline survey are listed in Table 7.2 and their spatial distribution shown in Figure 7.1. Livestock counts taken during the shoreline survey relate only to the time of the site visit on 18th and 21st July, 2011 and are dependent upon the viewpoint of the observer.

Table 7.2 Livestock observations from the shoreline survey

No.	Date	NGR	Description
1	18/07/2011	NB 11298 34436	Sheep droppings
2	18/07/2011	NB 11295 34444	Hoof prints along stream
3	18/07/2011	NB 11227 34405	Sheep droppings along the shore
4	18/07/2011	NB 11161 34400	Many sheep droppings, 2 sheep in view uphill from shore
5	18/07/2011	NB 11086 34395	Although the field is fenced from the shore, sheep droppings were frequent along the shore side of the fence
6	18/07/2011	NB 10984 34405	3 sheep seen up the hill and to the west
7	18/07/2011	NB 11027 34549	House, farm buildings, 7 sheep on shore side of road
8	18/07/2011	NB 11071 34609	4 cattle in field on land side of road
9	18/07/2011	NB 11095 34633	23 sheep in field behind home
10	18/07/2011	NB 11174 34650	27 sheep
11	18/07/2011	NB 11275 34603	8 sheep
12	18/07/2011	NB 11333 34585	8 sheep
13	18/07/2011	NB 10584 34613	Farm on the shore side of road with 32 sheep
14	22/07/2011	NB 10898 34679	10 cattle east of the road
15	22/07/2011	NB 11038 34562	3 pigs
16	18/07/2011	NB 10301 34483	Cattle droppings
17	18/07/2011	NB 09728 34640	Sheep droppings
18	18/07/2011	NB 09624 34271	19 sheep in field
19	18/07/2011	NB 09624 34221	Sheep droppings
20	18/07/2011	NB 09342 34370	2 horses on adjacent shore. 22 sheep in view on opposite shore
21	18/07/2011	NB 09310 34480	Sheep
22	21/07/2011	NB 08781 34719	2 sheep on shore
23	21/07/2011	NB 08381 34605	1 sheep
24	21/07/2011	NB 08866 34368	10 sheep with access to shore
25	21/07/2011	NB 08936 34382	5 sheep visible on opposite shore with approx. 20 more visible on hills above
26	21/07/2011	NB 08943 34312	7 sheep on hill above road
27	21/07/2011	NB 10171 32570	Hoof prints and sheep droppings on bank
28	21/07/2011	NB 10157 32796	9 sheep
29	21/07/2011	NB 10163 32893	6 sheep
30	21/07/2011	NB 10008 33241	7 sheep in fenced field adjacent to shore
31	21/07/2011	NB 09702 33385	12 sheep
32	21/07/2011	NB 09547 33385	Sheep pens, 6 sheep, 9 sheep further up hill
33	21/07/2011	NB 09934 33182	14 sheep uphill away from stream
34	21/07/2011	NB 10033 32964	9 sheep
35	21/07/2011	NB 10097 32741	East side of road - farm storage/animal housing
36	21/07/2011	NB 10144 32477	31 sheep east of burn
37	21/07/2011	NB 10180 32331	17 sheep east of burn
38	21/07/2011	NB 10180 32319	4 sheep west of burn
39	21/07/2011	NB 10195 32269	18 sheep east of burn

A total of 338 sheep, 14 cattle and 3 pigs were observed during the shoreline survey. Livestock were grazing extensively throughout the area and sheep droppings were observed around much of the shoreline. Small numbers of other livestock such as pigs, ducks and chickens were kept at some of the crofts. No arable farming was observed adjacent to the loch. The largest concentration of animals was found along the north shore to the east of the mussel farm. A flock of 19 sheep was observed near the shore west of the

mussel farm and evidence of recent livestock presence (hoof prints and dung or droppings) was observed to the north of the mussel lines. This area was closest of the observations to the mussel farm. Further livestock were recorded around Miavaig and along the B8011 between Miavaig and Cairisiadar.

During periods of heavy rain, runoff from land at these locations is likely to wash faecal material from the hillsides into the loch and any impact on the fishery is most likely to affect the lines nearest the shore. Livestock numbers are likely to be highest in summer, when lambs are present, and drop again in autumn when they are sent to market. Animals will tend to be kept on or near to croft areas and so distributions may not vary markedly from those observed during the survey.

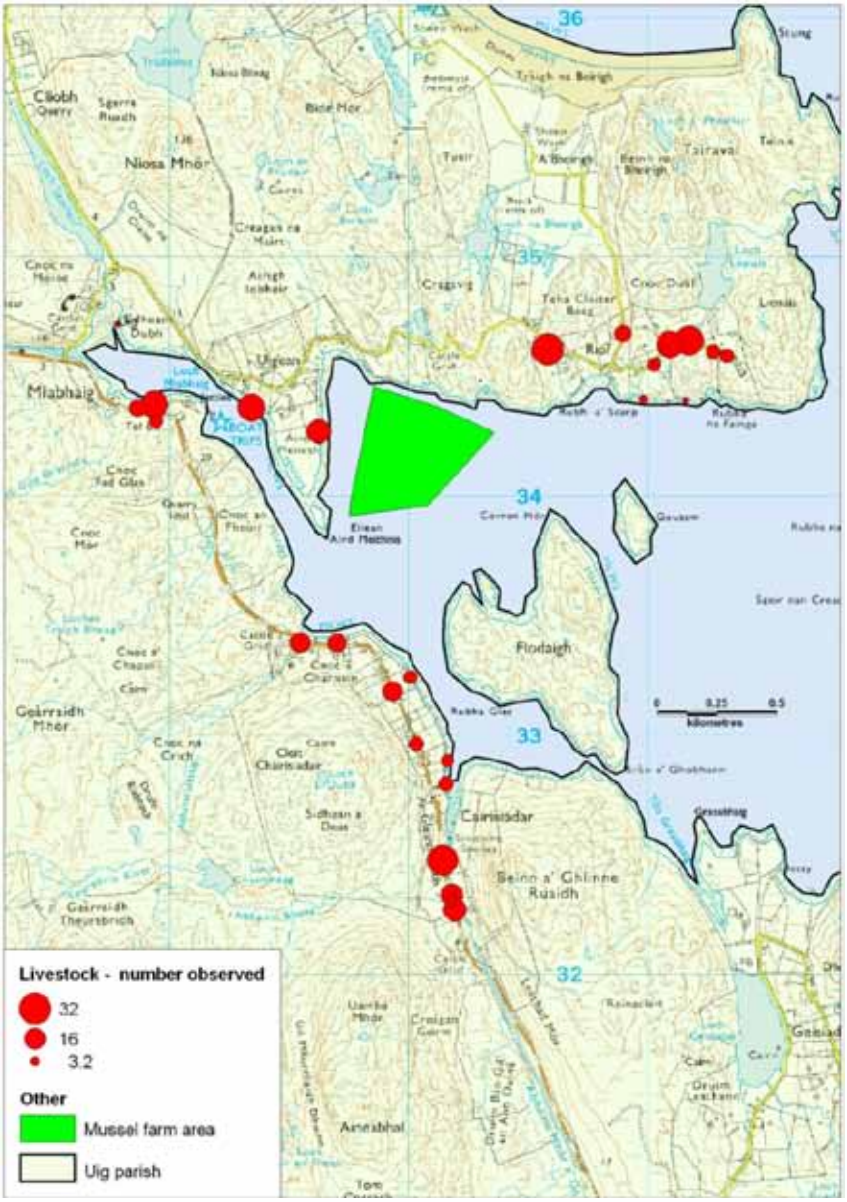

Figure 7.1 Livestock observations at Loch Roag: Miavaig

8. Wildlife

Wildlife is likely to be present in fishery areas and may contribute to the faecal bacterial load in a water body either via direct deposition of faeces or via diffuse runoff from land areas.

The Traigh na Berie Special Area of Conservation (SAC) is located inland to the northeast of the fishery area. The area was designated due to its machair habitat, which attracts a number of bird species, including geese. The Loch Roag Lagoons SAC lies on the north end of Great Bernera, to the northeast. The Glen Valtos Site of Special Scientific Interest (SSSI) is located upstream from the burn running into the head of Loch Miabhaig and is designated for quaternary geology and geomorphology.

The following are considered most likely to be present at or near the fishery.

Seabirds

Results from the Seabird2000 census (Mitchell *et al*. 2004) were used to ascertain the likely distribution and numbers of seabirds at or near the Miavaig production area. Records within 5 km of the mussel farm are listed in Table 8.1.

Table 8.1 Seabird counts within 5km of the Loch Roag: Miavaig fishery

Common name	Species	Count	Method
Arctic Tern	*Sterna paradisaea*	586	Occupied nests
Northern Fulmar	*Fulmarus glacialis*	1662	Occupied sites
Herring Gull	*Larus argentatus*	16	Occupied nests
Common Gull	*Larus canus*	18	Occupied nests
Black Guillemot	*Cepphus grylle*	541	Individuals on land
Great Black-backed Gull	*Larus marinus*	2	Occupied nests
Lesser Black-backed Gull	*Larus fuscus*	2	Occupied nests
European Shag	*Phalacrocorax aristotelis*	134	Occupied nests
Black-legged Kittiwake	*Rissa tridactyla*	62	Occupied nests
Black-headed Gull	*Larus ribibundus*	78	Occupied nests

Records showed an estimated total 3101 seabirds within a 5km radius of the fishery. The distribution of these relative to the mussel farm is shown in Figure 8.1. The closest observation is located on a small island, 2.3 km north east of the fishery. Birds flying over or feeding in waters at the mussel farms may directly deposit droppings near the mussel lines and so would have a greater impact on water quality when this occurs. Some species, such as gulls, are likely to be present year round and may rest on mussel floats. However, the majority of seabirds will only be present near shore during the summer nesting season, which is roughly from May to August and varies by species, with some arriving earlier and others staying later. Guano deposited around nest areas, however, is likely to wash off with rainfall over a longer period of time.

During the shoreline survey small numbers of seabirds including ducks, geese and oystercatchers were observed, the distribution of which are shown in Figure 8.1.

Waders and Wildfowl

Little information was available on the presence, numbers and seasonal variation in the populations of waders and wildfowl in Loch Roag. Some information was available pertaining to Lewis and Harris more broadly. A document on the birds of the Outer Hebrides produced by the Western Isles Natural History Society identified that the moorland and machair on Lewis & Harris were important areas for breeding waders and other birds (http://www.thewesternisles.co.uk/outer-hebrides-birds-checklist.pdf). It also suggested that Lewis & Harris did not attract the same number of wintering waders that the more southerly islands did. Given that moorland is common around the loch, it should be presumed that wading birds will contribute to background levels of faecal contamination found within the loch, particularly during the summer months when they are present. A small flock of oystercatchers were observed adjacent to the fishery, with one feeding on line adjacent to a float.

In 2008, 1914 greylag geese were found on Lewis & Harris (Mitchell *et al*, 2010) Post-moult counts of Greylag geese undertaken in August 2008 in North and South Uist indicated a strong association of the birds with grassland feeding areas (Mitchell *et al*. 2010). A large proportion of land around the proposed fishery was recorded as rough grassland and the Traigh na Berie SAC has machair habitat favoured by geese. During the shoreline survey, approximately twelve geese were observed south of the island of Flodaigh. A total of fifteen ducks and grouse droppings were also observed west of the fishery. Therefore, both geese and ducks may contribute to background levels of faecal contamination found at the Miavaig fishery.

Seals

The Western Isles hosts significant populations of both grey and common seals. The common seal population of the Outer Hebrides in 2008 was estimated at 1804, while the grey seal population was estimated to be 29700, with one breeding colony identified in outer Loch Roag (National Environment Research Council Special Committee on Seals, 2010). Both species are reported to be present in West Loch Roag. Seals forage widely for food and are likely to range throughout the loch and beyond, and therefore may only be present for a proportion of the time. These animals are likely to contribute to background faecal bacterial levels within the loch generally, and may lead to locally high levels of faecal contamination if they defecate in close proximity to the shellfish. No seals were seen during the survey, although the harvester reported that they were sometimes present in the area.

Otters

Otters are known to be present on the island and are likely to be present in Loch Roag. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be very minor. No otters were seen during the shoreline survey.

Deer

Deer are known to inhabit many parts of the island so it is likely that they may be present around Loch Roag. Faecal contamination from deer is most likely to be carried to the loch via freshwater streams and burns. The Visit Hebrides website identified that the population of deer on Lewis & Harris was just over 4000. (http://www.visithebrides.com/wildlife/topten/index.php, accessed 15/08/2011). Possible deer droppings were observed on the northern shoreline of Loch Miabhaig during the shoreline survey.

Whales and Dolphins

Due to the shallow depths found within the area of the fishery it is considered unlikely that even the smaller cetaceans such as porpoises and dolphins will frequent waters near the mussel farm.

Summary

Wildlife species in and around Loch Roag are likely to have a limited impact on bacteriological quality of water around the fishery due to the relatively small number of animals likely to be present compared with the large and open water area of the outer loch. Seals and seabirds may potentially directly deposit faeces to waters at the mussel farm, this is likely to be limited in extent and duration and relatively unpredictable. Other wildlife sources of faecal contamination are waterfowl and deer. Faecal material from both these sources is likely to be present in streams discharging to the loch. Therefore impacts may be higher near where streams and other freshwater runoff enter the loch. Waterfowl may also directly deposit droppings at or near the mussel lines anywhere within the fishery. No marked spatial distributions of seabirds were identified in the near vicinity of the fishery. However, impacts from this source are likely to be higher nearer the surface of the lines.

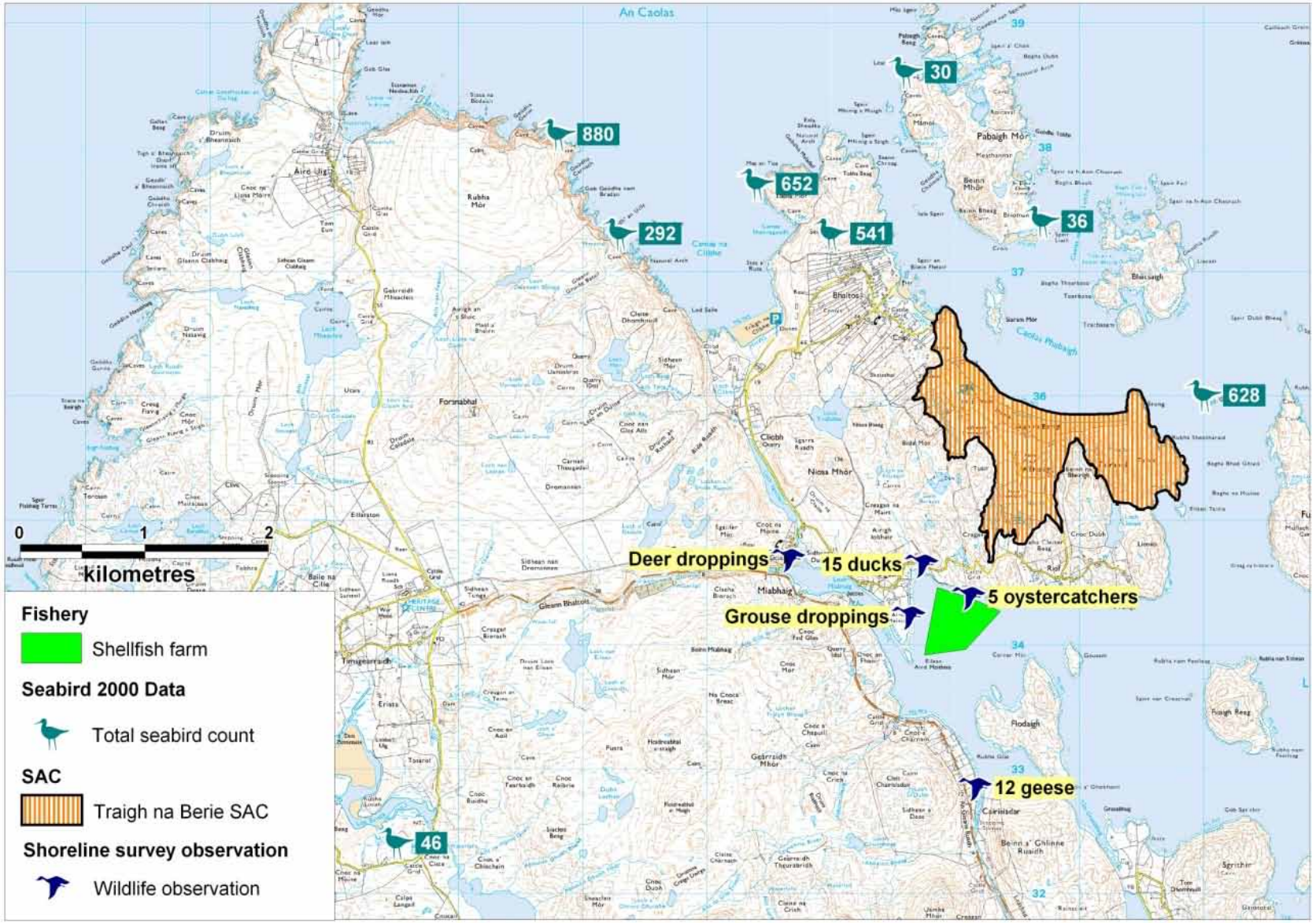

Figure 8.1 Map of seabird distributions

9. Meteorological data

Both rainfall and wind data were available for Stornoway airport, approximately 32 km east of the fishery. Rainfall data was available for 2003-2010 inclusive. Data for the stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch Roag: Miavaig.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The box and whisker plots in Figures 9.1 and 9.2 present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

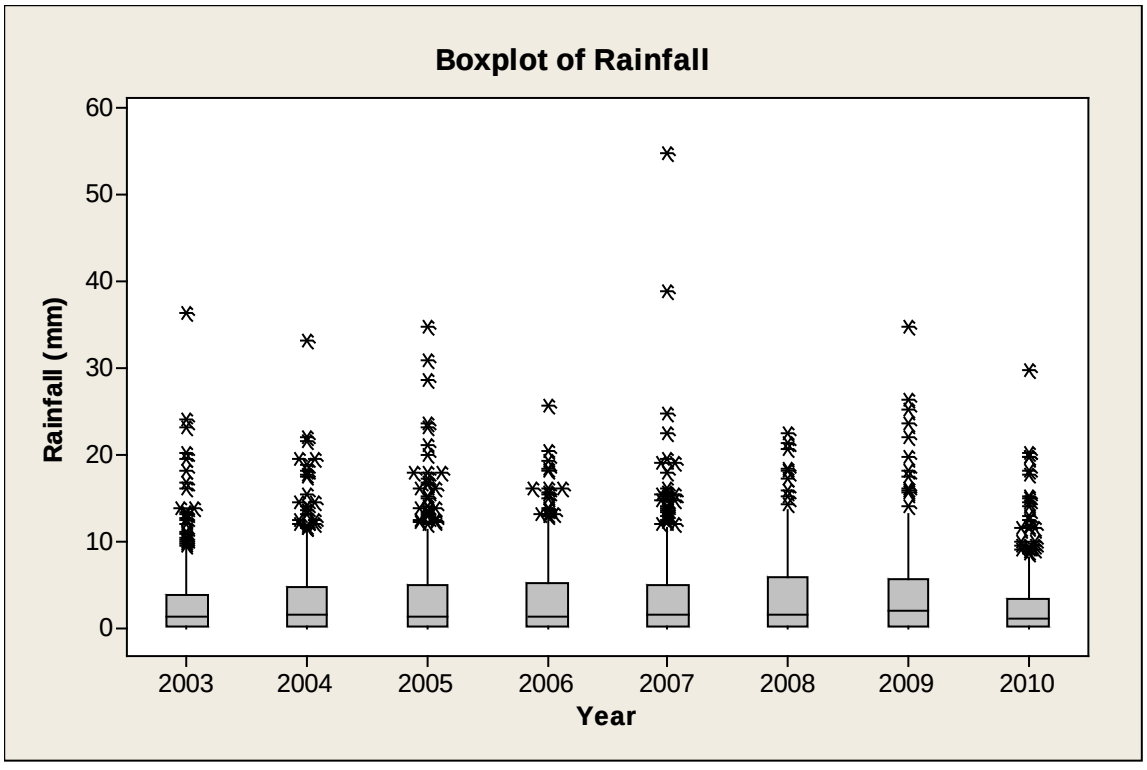

Figure 9.1 Box plot of daily rainfall values by year at Stornoway (2003 – 2010)

Figure 9.1 shows that rainfall levels were similar throughout the years with 2003 being the driest and 2008 the wettest.

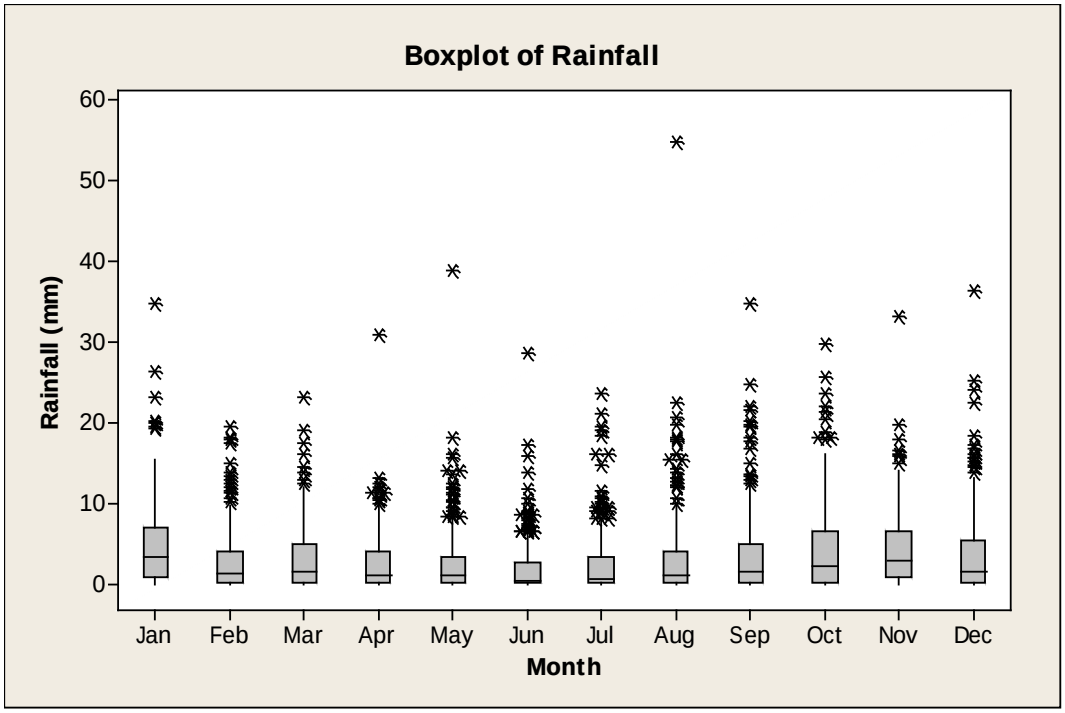

Figure 9.2 Box plot of daily rainfall values by month at Stornoway (2003 – 2010)

Figure 9.2 shows that monthly rainfall occurs at its highest through the months of January, October and November. More extreme rainfall events (>20 mm in a day) occurred throughout all the months, with no obvious seasonal pattern. For the duration considered here (2003 – 2010), 43% of days experienced less than 1mm of rainfall and 7% of days experienced rainfall of 10mm or more.

The potential for increased run-off is therefore highest in autumn and winter. However, the amount of contamination in any run-off will depend on the higher rainfall levels occurring when faecal contamination is present on the land. This is most likely in the late summer and early autumn periods.

9.2 Wind

Wind data collected at the Stornoway weather station is summarised by season and presented in figures 9.3 and 9.4.

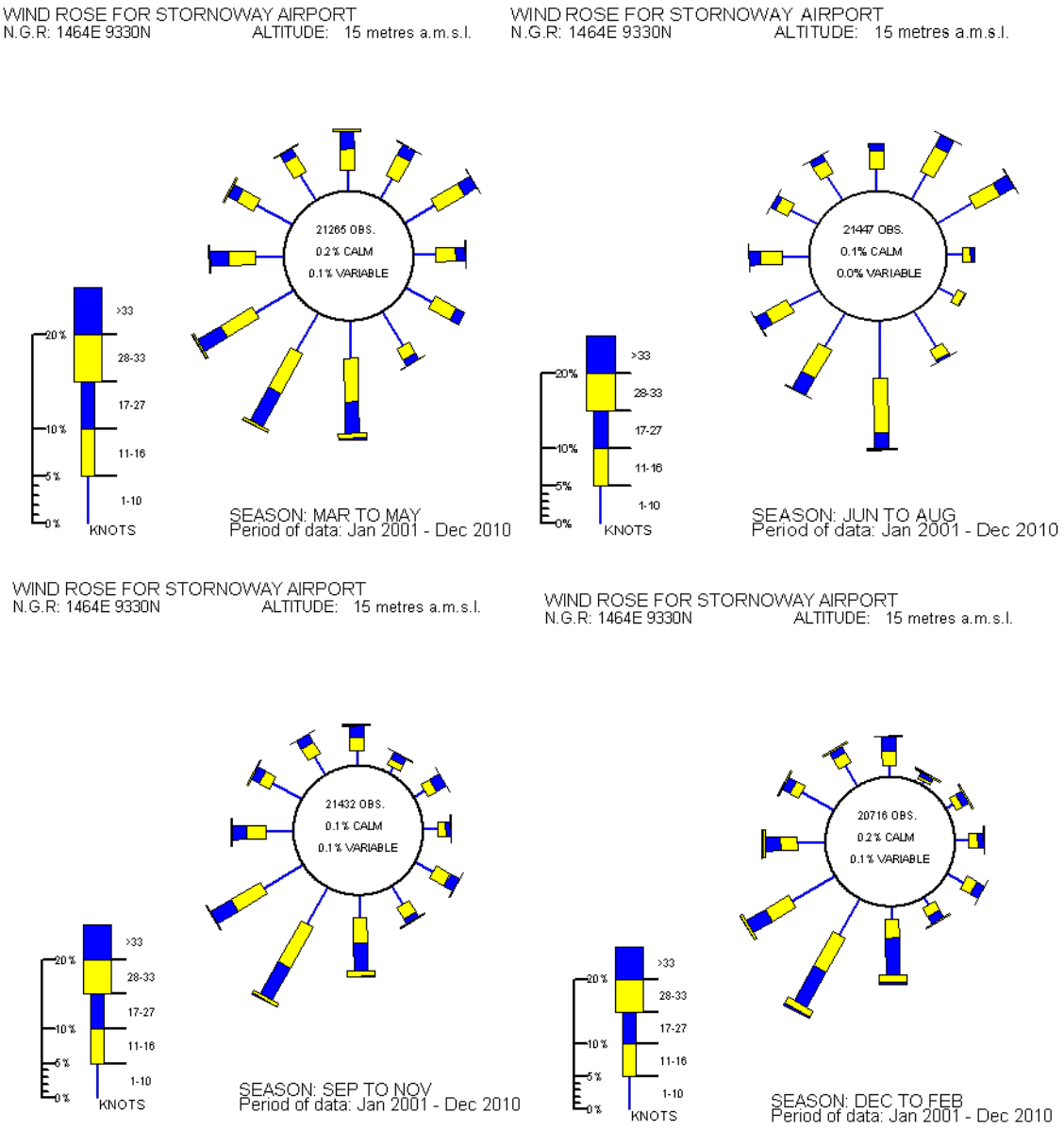

Figure 9.3 Seasonal wind roses for Stornoway Airport

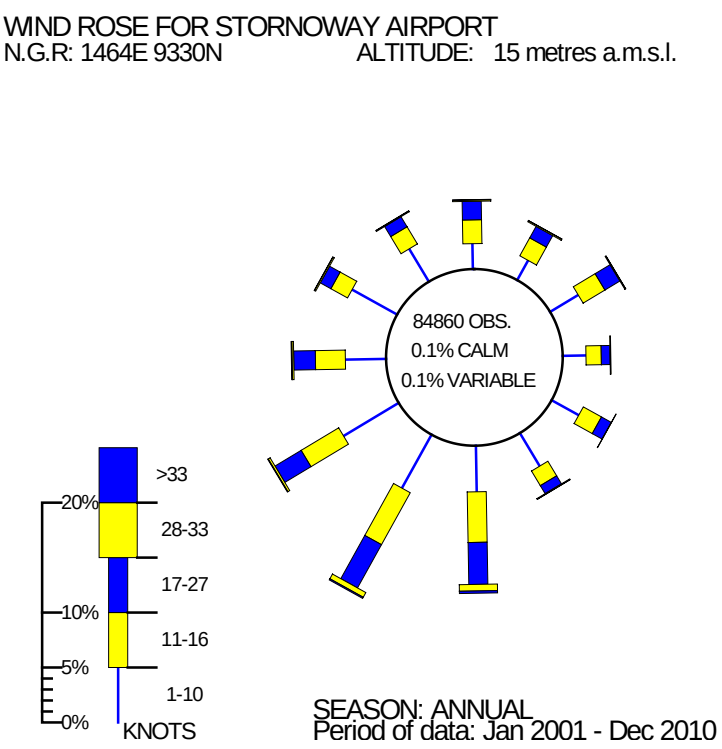

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Figure 9.4 Annual wind rose for Stornoway Airport

The prevailing wind direction at Stornoway is from the southwest. There is a higher occurrence of north easterly winds during the spring and summer. Winds are generally lightest in the summer and strongest in the winter. The terrain surrounding Stornoway airport is relatively low lying and so the station is exposed to wind from all directions.

Winds typically drive surface water at about (3%) of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds, particularly those from the directions to which it is most exposed will significantly alter the pattern of surface currents at within Loch Roag; Linngeam, Torranish and Drovinish. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock at and above the normal high water mark, into the production area.

10. Current and historical classification status

Loch Roag: Miavaig has been classified for the production of common mussels (*Mytilis* sp) since 2004. Prior to 2004, this area may have been classified under a different designation. The historical and current classifications for the production area are shown below in Table 10.1.

Table 10.1 Loch Roag Miavaig, Common Mussels

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2004	A	A	A	A	A	A	A	B	B	A	A	A
2005	A	A	A	A	A	A	A	A	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	B	B	B	A	A
2010	A	A	A	A	A	A	A	B	B	B	B	A
2011	A	A	A	A	A	A	A	B	B	B	B	A

Loch Roag: Miavaig held an A classification year round for 2005 – 2008. Where the remaining years have mixed A/B classification, the months classified as B have occurred in late summer and autumn.

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all mussel samples taken at Loch Roag: Miavaig from 1 January 2007 up to 31 December 2011 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database in February 2012. All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

Five results were recorded as having been rejected by FSAS and these were deleted from the data set. One of these appeared to be a duplicate of a valid entry. All of the remaining samples were received by the testing laboratory within two days of collection. The reported coolbox temperatures were all ≤8°C. Five samples were recorded as having sampling locations outside the current production area boundaries. No obvious digit transpositions were present and the maximum distance from the boundary was 230 m: the results were kept in the data set for analysis.

Eighteen samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. No sample had a result reported as >18000.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Roag: Miavaig
Site	Miavaig
Species	Common mussels
SIN	LH 188 123 08
Location	Various
Total no of samples	56
No. 2007	10
No. 2008	11
No. 2009	12
No. 2010	12
No. 2011	11
Results Summary	
Minimum	<20
Maximum	2400
Median	20
Geometric mean	45
90 percentile	867
95 percentile	2400
No. exceeding 230/100g	10 (18%)
No. exceeding 1000/100g	2 (4%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

11.3 Overall geographical pattern of results

Of the 56 samples included in the analyses 10, taken in 2007, were reported to 100 m accuracy and against 6 different locations. The 46 samples taken since the beginning of 2008 were reported to an accuracy of 10 m: these were reported against 41 separate locations. The reported sampling locations are plotted in Figure 11.1 with the size of the symbol graduated according to the *E. coli* result of the sample.

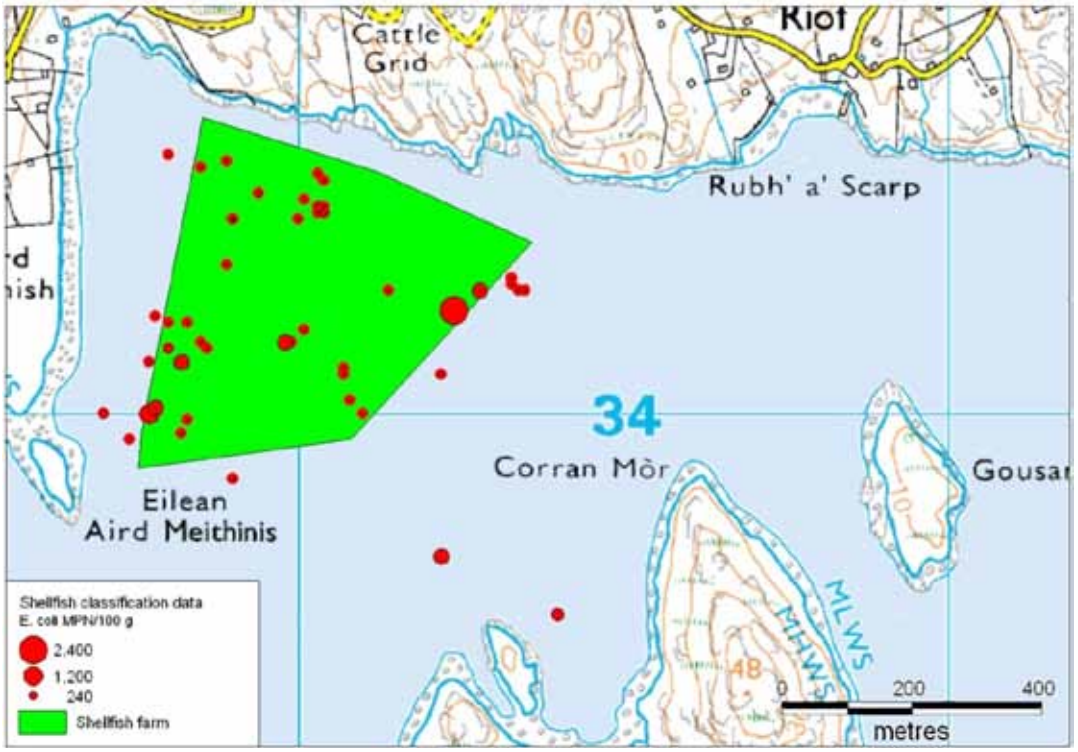

Figure 11.1 Map of sampling locations

The figure shows a tendency for higher results to be seen in samples taken from locations in a band across the fishery along a line from Eilean Aird Meithinis to Rubh' a' Scarp.

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual *E. coli* results against date, fitted with a loess smoother line. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The smoother line helps to highlight any apparent underlying trends or cycles.

There appears to have been no change in the underlying level of *E. coli* contamination in the fishery over the five years. There is a general tendency towards lower results in the first part of the year.

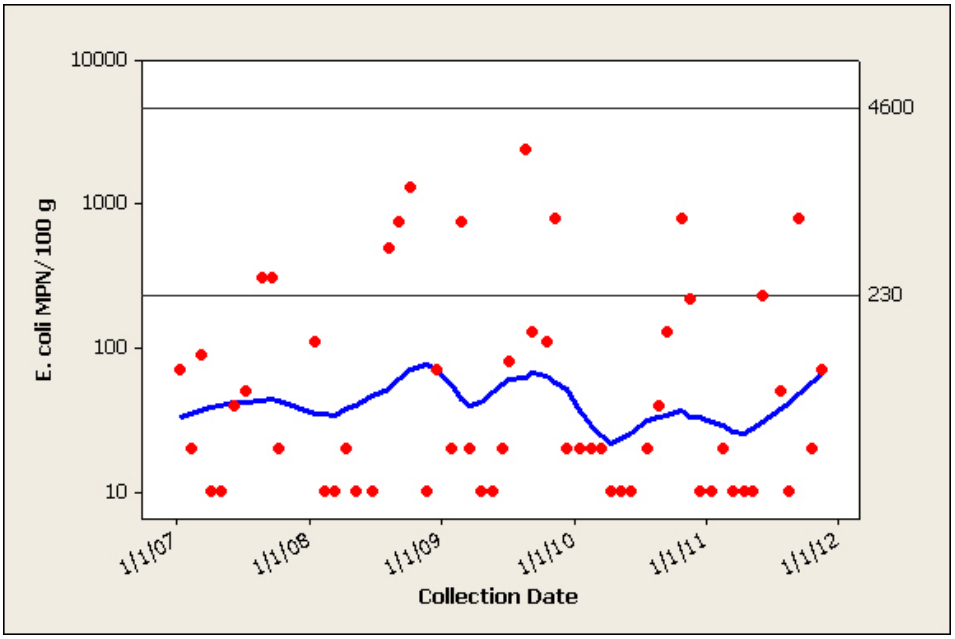

Figure 11.2 Scatterplot of *E. coli* results by date with loess line

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figure 11.3 presents a scatterplot of *E. coli* result by month, superimposed with a loess smoother line.

The graph emphasizes the lower results in the first part of the year, with the lowest being in April and May, with the highest results tending to occur between August and November.

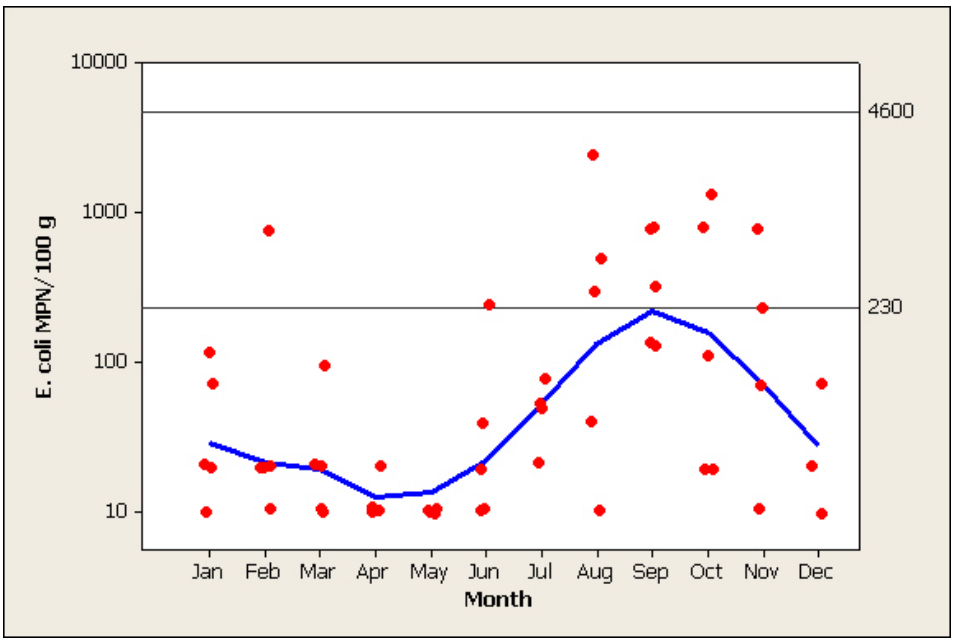

Figure 11.3 Scatterplot of results by month

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of results by season are shown in Figure 11.4.

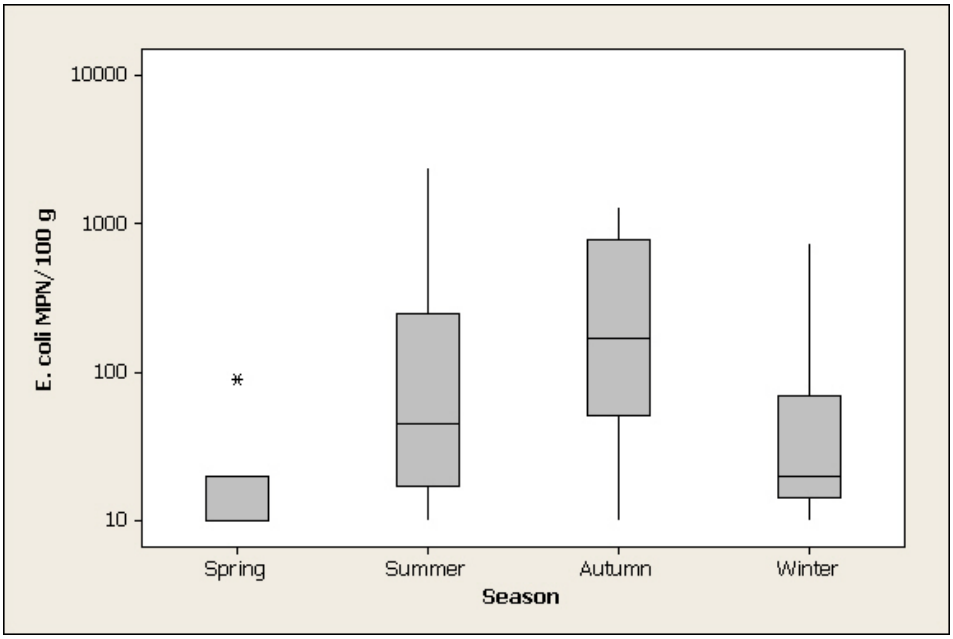

Figure 11.4 Boxplot of result by season

A significant difference was found between results by season (One-way ANOVA, $p<0.001$, Appendix 4). A post-ANOVA analysis (Tukey's method) showed that the results in spring were significantly lower than those in summer and autumn and that those in winter were significantly lower than those in autumn.

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest Meteorological Office weather station to Loch Roag: Miavaig is at Lewis: Creed Bridge, approximately 28 km to the east of the production area. However, more complete data was available for the station at Stornoway Airport, a further 6 km to the east, Rainfall data was purchased from the Meteorological Office for the period up to 31/12/2010 (total daily rainfall in mm). Daily rainfall data was not available for just one day during the period 1/01/2007 to 31/12/2010.

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against rainfall in the previous two days. A Spearman's Rank correlation was carried out between results and rainfall. A highly significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.450, p=0.002). However, the highest results were seen after moderate amounts of rainfall (approximately 20 mm) and results greater than 230 *E. coli* MPN/100 g occurred even after no recorded rainfall. The effect with rainfall appeared therefore to be due primarily to the absence of low recorded results after increasing rainfall, rather than the absence of high results at low rainfall levels.

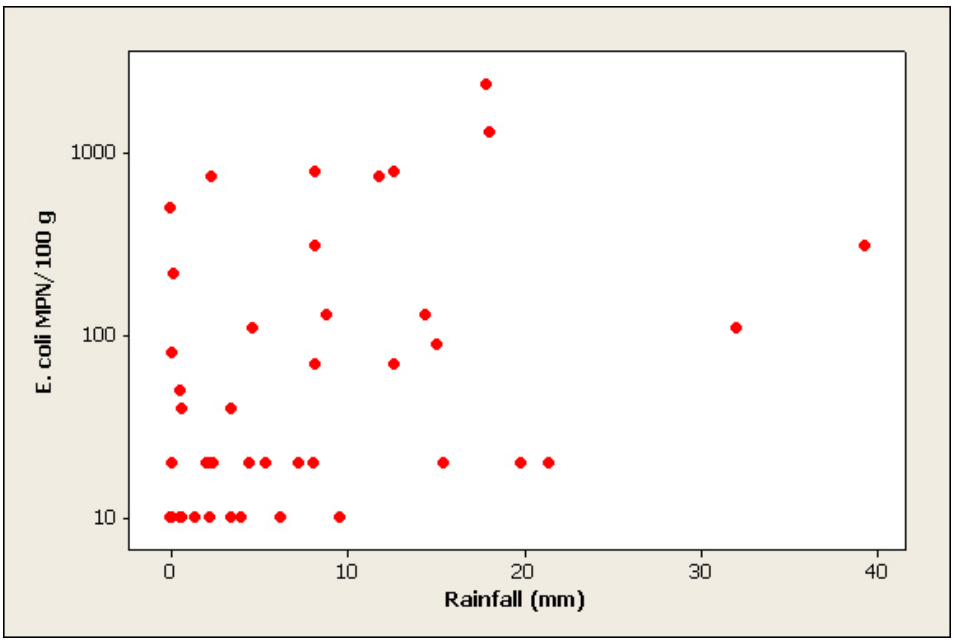

Figure 11.5 Scatterplot of result against rainfall in previous 2 days

Seven-day antecedent rainfall

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above.

A scatterplot of *E. coli* results against rainfall is presented in Figure 11.6.

A highly significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation=0.431, p=0.003). However, the highest results were seen after moderate amounts of rainfall (approximately 40 mm).

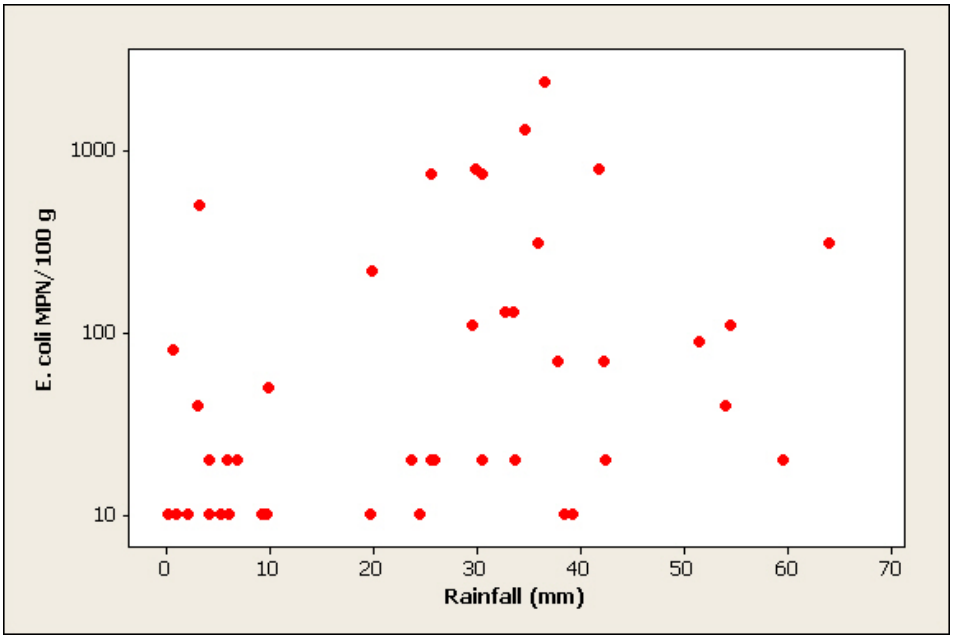

Figure 11.6 Scatterplot of result against rainfall in previous 7 days

11.6.2 Analysis of results by tidal height and state

Spring/Neap Cycle

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

No significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.162, p=0.250).

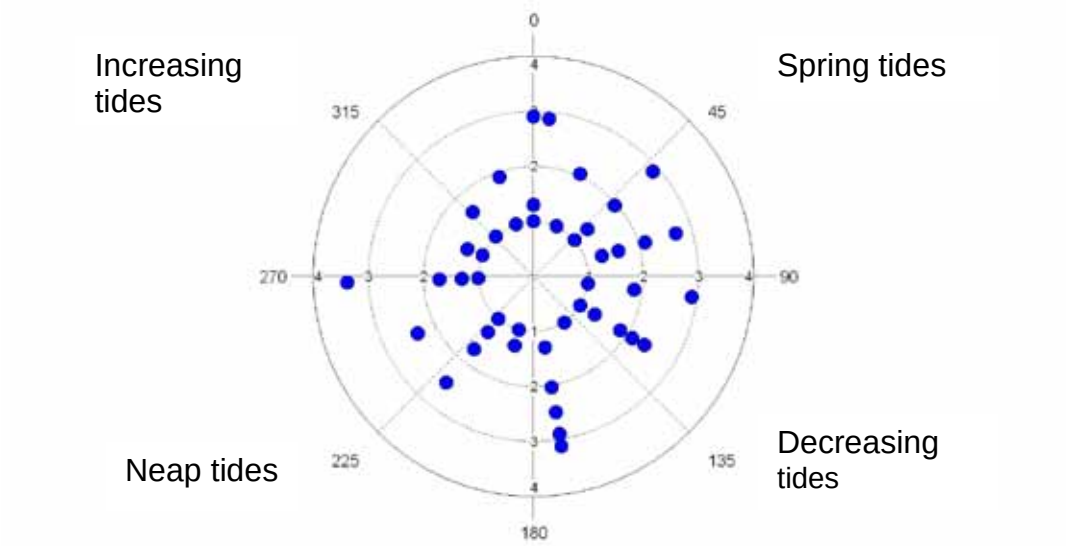

Figure 11.7 Polar plot of log_{10} *E. coli* results on the spring/neap tidal cycle

High/Low Cycle

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of log_{10} *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

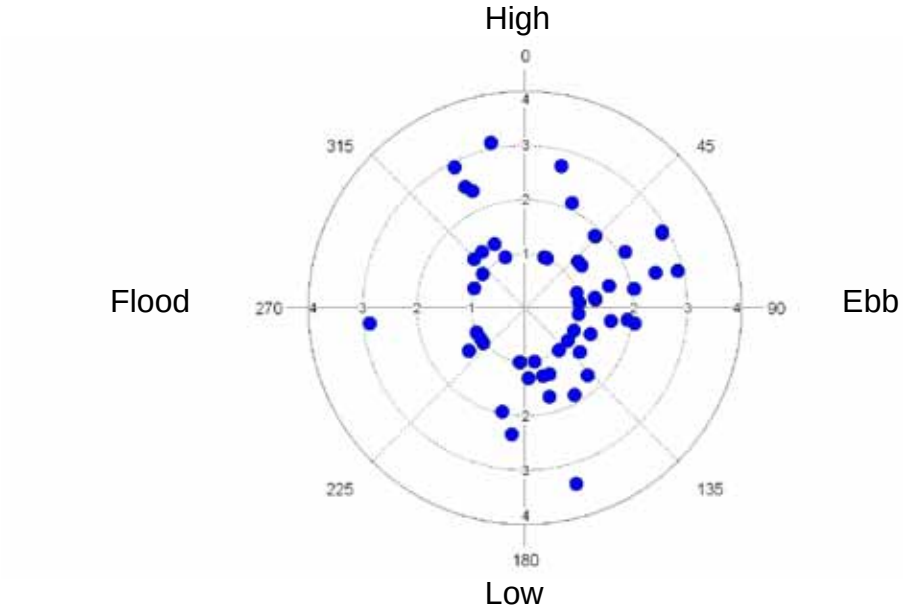

Figure 11.8 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle

A significant correlation was found between log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.264, p=0.025). Higher

results tended to occur around high water and over the first half of ebb tide. However, the highest result was seen in a sample taken around low tide.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.9 presents a scatterplot of *E. coli* results against water temperature.

Seawater temperature was recorded for 16 of the 56 mussel sampling occasions for the data analysed. No significant correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.306, p=0.249).

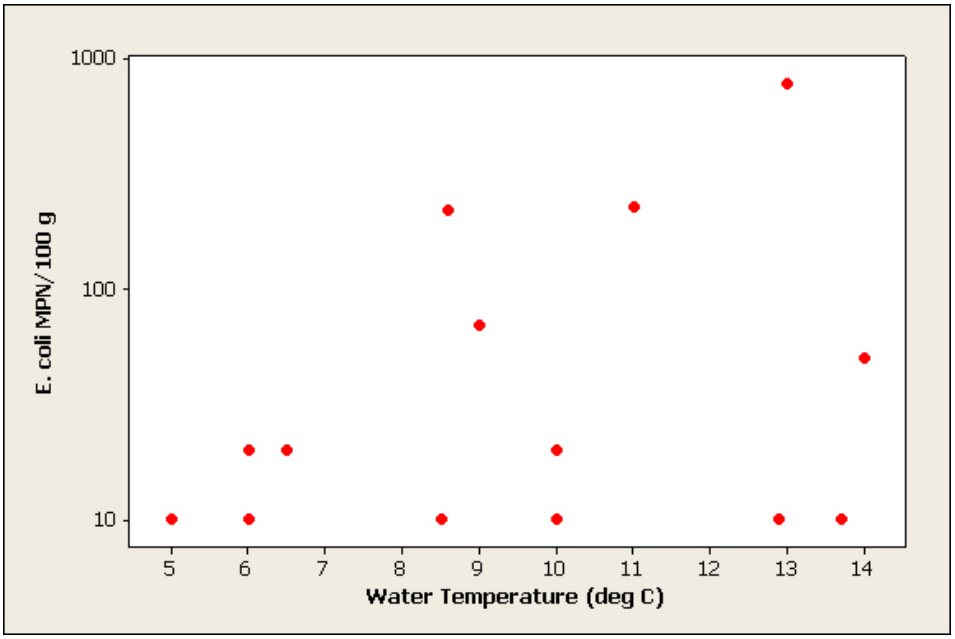

Figure 11.9 Scatter plot of log_{10} *E. coli* results against water temperature

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater-borne contamination at the site. Figure 11.10 presents a scatter plot of *E. coli* result against salinity.

Salinity was recorded for 49 of the 56 mussel sampling occasions for the data analysed. No significant correlation was found between *E. coli* result and salinity (Spearman's rank correlation= -0.211, p=0.146).

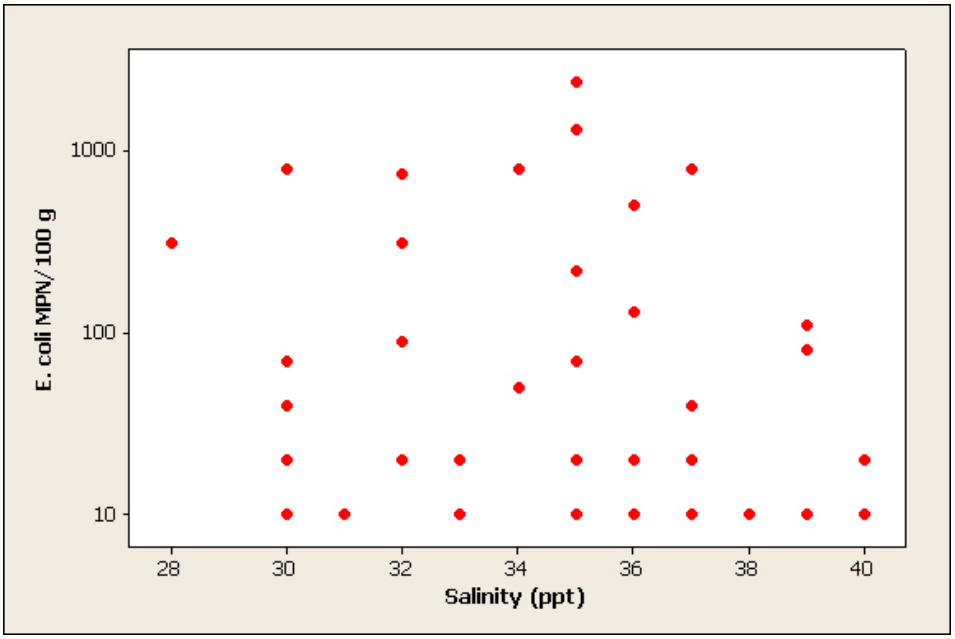

Figure 11.10 Scatter plot of log_{10} *E. coli* results against salinity

11.7 Evaluation of results over 230 *E. coli* MPN/100g

Of the 56 mussel samples, 10 gave results of over 230 *E. coli* MPN/100g. Details of these samples are presented in Table 11.2.

Table 11.2 Historic *E. coli* sampling results over 230 *E. coli* MPN/100g

Collection date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (°C)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
21/08/2007	310	NB 097 340	39.2	64.0	*	28	High	Neap
18/09/2007	310	NB 098 341	8.2	35.9	*	32	Ebb	Decreasing
04/08/2008	500	NB 1040 3369	0.0	3.3	*	36	High	Spring
01/09/2008	750	NB 1022 3378	11.8	25.7	*	32	Ebb	Spring
06/10/2008	1300	NB 0977 3400	18.0	34.7	*	35	High	Decreasing
24/02/2009	750	NB 0978 3401	2.3	30.5	*	*	Flood	Increasing
17/08/2009	2400	NB 1024 3416	17.8	36.5	*	35	Low	Increasing
09/11/2009	790	NB 1028 3419	8.2	41.8	*	30	High	Decreasing
27/10/2010	790	NB 0998 3411	12.6	29.9	*	37	Ebb	Decreasing
12/09/2011	790	NB 0982 3408	*	*	13	34	Ebb	Increasing

*Data not available

Apart from one sample taken in February, they were taken between August and November. The sampling locations all lay approximately along a line between Eilean Aird Meithinis and Rubh' a' Scarp, towards the outer (south-eastern) part of the fishery. There was no pattern with respect to the spring/neap tidal cycle but most of the samples had been taken around high water or on the first half of the ebb tide. The majority of samples had been taken after moderate rainfall. Samples had been taken over a range of salinities. Seawater temperature was only available for one sample.

11.8 Summary and conclusions

Samples had been taken at a wide range of locations on, and in the vicinity of, the area coinciding with the present mussel lines. The highest results were seen along a line running near the outer part of that area. In general, the extent of contamination has not changed over time. There was a significant seasonal effect with highest results occurring in the summer and autumn: however, there was no significant effect of seawater temperature (although this information was missing for most of the high results). There was a significant correlation of the *E. coli* levels in the shellfish with rainfall but this was not reflected in a correlation with salinity. There was no effect of the spring/neap tidal cycle but a significant correlation was seen with the high/low tidal cycle and most of the high results occurred in samples taken around high water or over the first half of the ebb tide.

11.9 Sampling frequency

When a production area holds a non-seasonal classification, and where at least 24 results are available over the past 3 years, and the geometric mean of those results falls within a certain range, consideration can be given to reducing the sampling frequency from monthly to bimonthly. The area is currently a seasonal A/B and so this consideration does not apply.

12. Designated Shellfish Growing Waters Data

The Miavaig production area all falls within the Loch Roag designated shellfish growing water. The area was redesignated in 2002 and a full monitoring regime implemented in 2005. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in shore mussels. Prior to redesignation in 2002 the Fisheries Research Services (FRS) used the Loch Roag Miavaig sampling point at NN 099 343, sample results are shown in Table 12.1. From 2003, the sampling point used for SGW monitoring at Loch Roag was NB 16000 34000. This lies on the eastern side of the loch, 6 km from the Miavaig fishery. As this location is likely to be subject to differing sources and effects from movement of contaminants than at Miavaig, results from the eastern monitoring point are not considered here.

The relative positions of the SGW boundary, mussel farm and SGW monitoring points are shown in Figure 12.1.

Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Those results have been used in the analysis in Section 11 of this report and so are not repeated here.

Table 12.1 SEPA monitoring results for shore mussels - Loch Roag

Year	Quarter	Faecal coliform results (FC/100g)
		Loch Roag Miavaig NN 09900 34300
1999	Q4	40
2000	Q1	50
	Q2	-
	Q3	-
	Q4	110
2001	Q1	-
	Q2	20
	Q3	20
	Q4	-
2002	Q1	<20
	Q2	<20
	Q3	310
	Q4	<20
2003	Q1	20
	Q2	-
	Q3	-

- No result reported

Results ranged from <20 to 310 FC/100g, indicating relatively low levels of faecal contamination at the time of sampling.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Consequently, the results presented in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

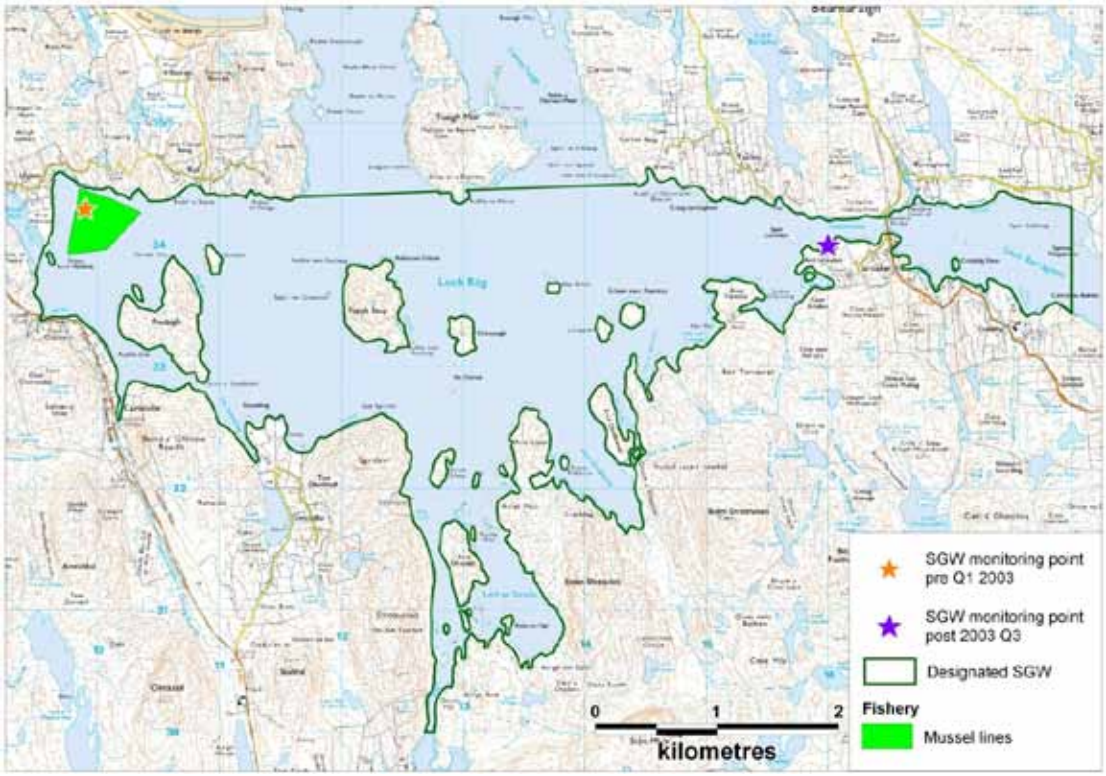

Figure 12.1 Designated shellfish growing water – Loch Roag

13. River Flow

There are no gauging stations on watercourses discharging to Loch Roag.

The watercourses listed in Table 13.1 and mapped in Figure 13.1 were measured and sampled during the shoreline survey. Heavy rain occurred prior to, and during, the first two days of the survey.

Table 13.1 River (or stream) loadings for Loch Roag: Miavaig

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	NB 11305 34431	Stream	Not measured or sampled[1]					
2	NB 11295 34444	Stream	0.4	0.05	0.399	689.472	3600	2.5×10^{10}
3	NB 11118 34406	Stream	0.2	0.03	1.039	538.6176	90000	4.8×10^{11}
4	NB 10972 34410	Stream	Not measured or sampled[1]					
5	NB 10936 34429	Stream	Not measured or sampled[1]					
6	NB 10834 34494	Stream	0.3	0.08	0.47	974.592	3800	3.7×10^{10}
7	NB 10732 34464	Stream	Not measured or sampled					
8	NB 10670 34382	Stream	0.22	0.07	0.0302	40.18291	7200	2.9×10^{9}
9	NB 10788 34496	Stream	Not measured or sampled[1]					
10	NB 10306 34465	Stream	0.55	0.06	0.092	262.3104	500	1.3×10^{9}
11	NB 09632 34572	Stream	1	0.12	0.142	1472.256	500	7.4×10^{9}
12	NB 09636 34525	Stream	0.31	0.03	0.06	48.2112	800	3.9×10^{8}
13	NB 08729 34860	Culverted stream from Loch Sgailleir	0.8	0.1	0.176	1216.512	58	7.1×10^{8}
14	NB 08309 34607	Abhainn a' Ghlinne	1.7	0.26	0.183	6988.55	300	2.1×10^{10}
15	NB 08741 34404	Allt Gile Brùnnda	0.25	0.08	0.168	290.304	100	2.9×10^{8}
16	NB 08903 34366	Stream	Not measured or sampled[1]					
17	NB 09085 34588	Stream	0.2	0.03	0.244	126.4896	300	3.8×10^{8}
18	NB 10027 34641	Drainage from lake	Not measured or sampled[1]					
19	NB 10189 32352	Abhainn Mhòr a' Ghlinne Ruaidh	4.5	0.265	0.208	21430.66	100	2.1×10^{10}
20	NB 10105 33085	Stream	Not measured or sampled[1]					
21	NB 09547 33385	Abhainn Uasaig	Not measured or sampled[1]					

Note: [1]Insufficient flow to measure.

In general, the estimated loadings for the sampled and measured watercourses were moderate and, under similar rainfall conditions, would be expected to impact on the water quality in the area. The two streams located near Uigean have the potential to directly impact on the microbiological quality of the mussels at the north-western corner of the lines. The watercourses on the outer northern shore (including the Reef area) will potentially impact on the northern part of the lines while those located within Loch Miabhaig will

generally add to the contamination levels within the outer area during an ebb tide and may specifically impact on the south-western corner of the lines.

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Figure 13.1 Map of river/stream loadings at Loch Roag: Miavaig

Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

14. Bathymetry and Hydrodynamics

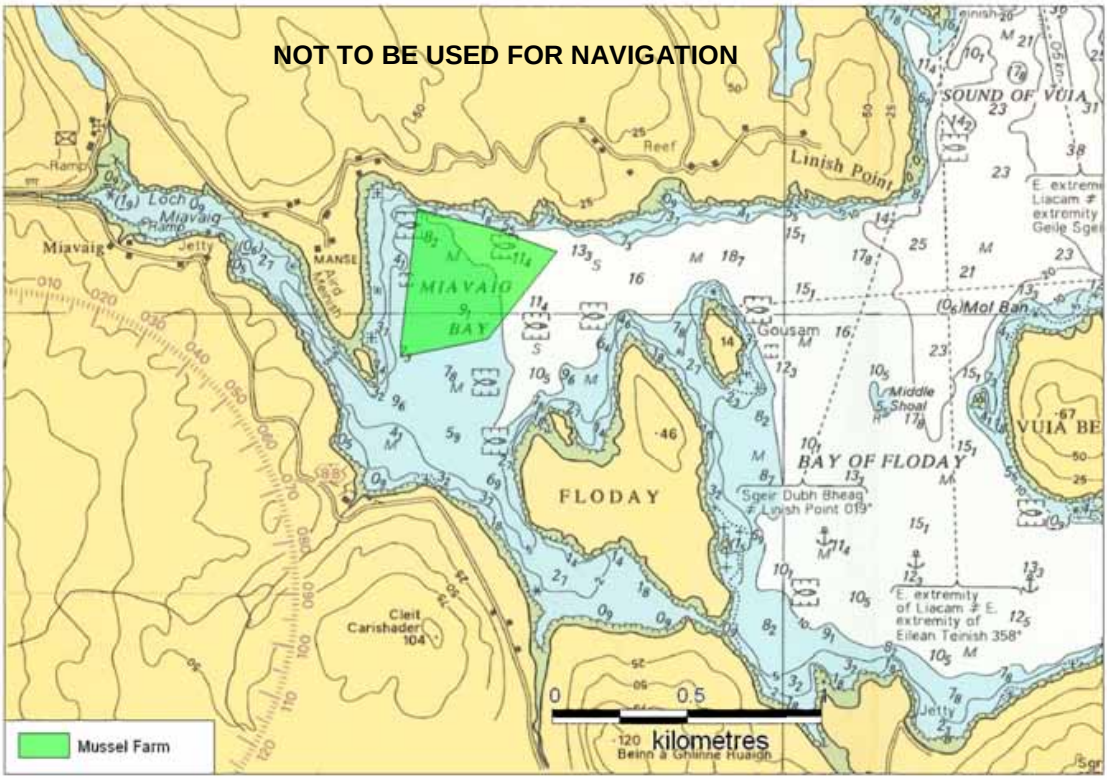

Figure 14.1 Bathymetry at Loch Roag: Miavaig

Loch Roag is a large, complex sea loch situated on the western coast of the Isle of Lewis. It opens to the sea to the north. Loch Roag West, Loch Roag and Loch Roag East essentially form three water bodies. West and East Loch Roag lie either side of Great Bernera island. West Loch Roag and Loch Roag lie either side of Vuia Mòr while Loch Roag and East Loch Roag are connected by a strait between Great Bernera and the mainland of Lewis. There are a large number of islands and inlets within Loch Roag: a number of the latter are named as separate lochs. One of the latter is Loch Miabhaig, at the western end of the area depicted in Figure 14.1. The mussel farm that is the subject of the present report is situated in Miavaig Bay.

Charted depths in the vicinity of the mussel lines vary from just over 5 metres close to shore in to more than 11 metres at the outer part in the channel between mainland and Floday. It should be noted that the depths on the chart are based on an Admiralty leadline survey undertaken in 1902. The extent of drying areas is limited around the rocky shore to the north of the farm but is slightly more extensive along the western shore of the bay and on the north-western side of Floday. The channel between Aird Meinish and Eilean Aird Meinish dries at low tide. There is an extensive drying area on the northern side of the head of Loch Miabhaig.

14.1 Tidal Curve and Description

The two tidal curves below are for Little Bernera, located on the north side of Great Bernera. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 18/07/11 and the second is for seven days beginning 00.00 BST on 25/07/11. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle and cover the period during which the shoreline survey was undertaken.

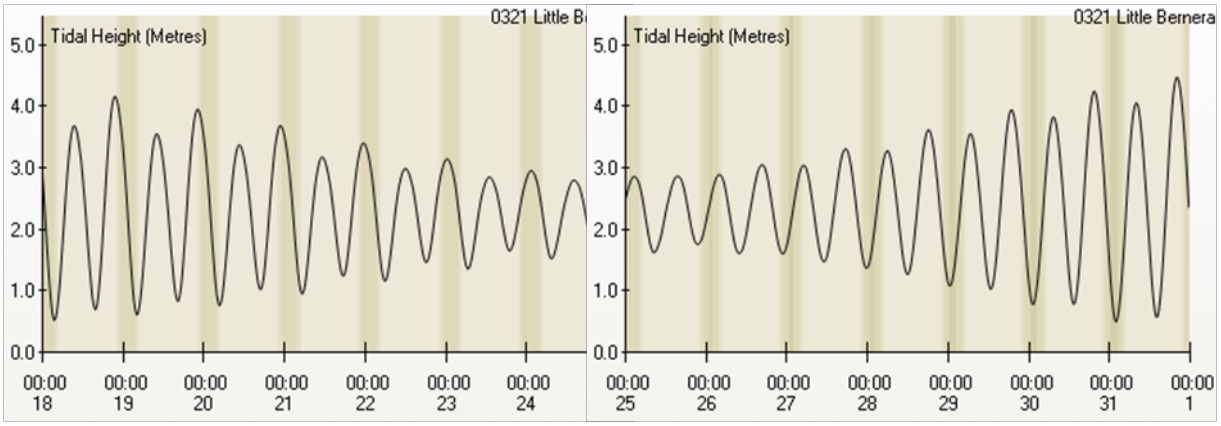

Figure 14.2 Tidal curves for Little Bernera

The following is the summary description for Little Bernera from TotalTide:

0321 Little Bernera is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	5.2 m
MHWS	4.3 m
MHWN	3.1 m
MLWN	1.6 m
MLWS	0.5 m
LAT	-0.1 m

Predicted heights are in metres above chart datum. The average tidal range at spring tide is 3.8 m and at neap tide 2.6 and so tidal ranges at this location are moderate (mesotidal).

14.2 Currents

There is no tidal stream information on the hydrographic chart for Miavaig Bay or Loch Miabhaig. However, tidal stream arrows on the chart indicate that the flood tide stream in the Sound of Vuia reaches 0.5 knots (approximately 0.25 m/s), flowing approximately southwards. They also indicate that the ebb tide stream reaches the same speed in the opposite direction.

SEPA provided current meter study data for three locations within Loch Roag. The locations are shown in Figure 14.3. The survey periods were as given in Table 14.1. Unfortunately, none of the locations were in close vicinity to the mussel farm. However, the data will inform the general assessment of current movements within Loch Roag.

Table 14.1 Survey periods for the fish farm current meter studies

Location	NGR	Survey period
Gousam	NB 11227 33758	07/07/2009-22/07/2009
Vuia Beag	NB 12109 32983	07/07/2009-22/07/2009
Kyles Vuia	NB 13514 35413	06/05/2004-03/06/2004

Polar plots of the current directions and speeds at the three locations, together with the wind direction and speeds over the relevant periods, are shown in Figure 14.4. Currents are presented in cm/s. Wind speeds are presented in m/s. As per convention, currents are plotted against the direction towards which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range. Clear areas at the centre of each plot are proportional to the amount of data showing no, or negligible, current. Directions are in degrees magnetic.

The plots show that there were no or imperceptible currents at both Gousam and Vuia Beag over a large proportion of the monitoring period, with the proportions being greater at mid-depth and near-surface at Gousam than Vuia Beag. At Gousam, there is some directional component at mid-depth and near-surface but this differs between the two depths. Current speeds at the two locations were all <15 cm/s (0.15 m/s; 0.3 knots).

In contrast, the plots for Kyles Vuia show a marked bidirectional current, the directions of which coincide with that of the channel and the tide stream arrows on the hydrographic chart. Maximum current speeds were in the region of 40 cm/s (0.4 m/s; 0.8 knots). This is a little larger than the 0.4 knots indicated on the hydrographic chart.

The current plots for Goussam are more likely to be similar to the situation that applies within Miavaig Bay and so currents there are expected to be very weak and without a clear directional component.

It has been calculated that the flushing time for West Loch Roag (including the Loch Roag basin) is approximately 8 tidal cycles (4 days) (Tyrer & Bass, 2005). This is a moderate flushing time: that calculated for other lochs varies between 0 and 14 days (Edwards & Sharples, 1991). Tyrer and Bass calculated the mean daily water exchange in West Loch Roag as 248 million m^3/day.

14.3 Salinity effects

One salinity profile was recorded during the shoreline survey. The location is shown in Figure 14.5 and the results are given in Table 14.2.

Table 14.2 Salinity profile results

Profile	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	19/07/2011 10:14	NB 0985 3446	0	35.5	13.6
			1	35.6	13.6
			3	35.6	13.6
			5	35.6	13.6

The profile did not show any differences in salinity or temperature between the three depths. Salinity results (from laboratory analyses) for spot seawater samples taken during the survey gave results that varied between 31.8 and 37.4 ppt. The lower values were obtained from some of the samples obtained from the shore, indicating the effect of nearby freshwater influences.

14.4 Conclusions

Currents within the area are generally weak and flows to the north and north-east predominate over much of the tidal cycle. Current flows in the vicinity of the mussel lines will follow the direction of the Sound of Vuia and will thus run parallel to the shore. Given the generally low current speeds, there is the potential for wind-driven flows to be significant. Within Miavaig Bay, south-westerly winds may tend to increase the effects of the ebb tide and reduce the effect of the flood tide. However, there was no indication of wind effects in the current data analyses.

On the ebb tide, the north-west corner of the lines will be exposed to contamination arising in the vicinity of Uigean while the south-west corner of the lines may be exposed to contamination coming out of Loch Miabhaig. However, the latter effect may be reduced because of the drying channel between Aird Meinish and Eilean Aird Meinish: once this is exposed, flows will be diverted round the southern end of the island and away from the fishery. On the flood tide, the north-eastern corner of the lines may be exposed to contamination arising from the area around Riof (Reef).

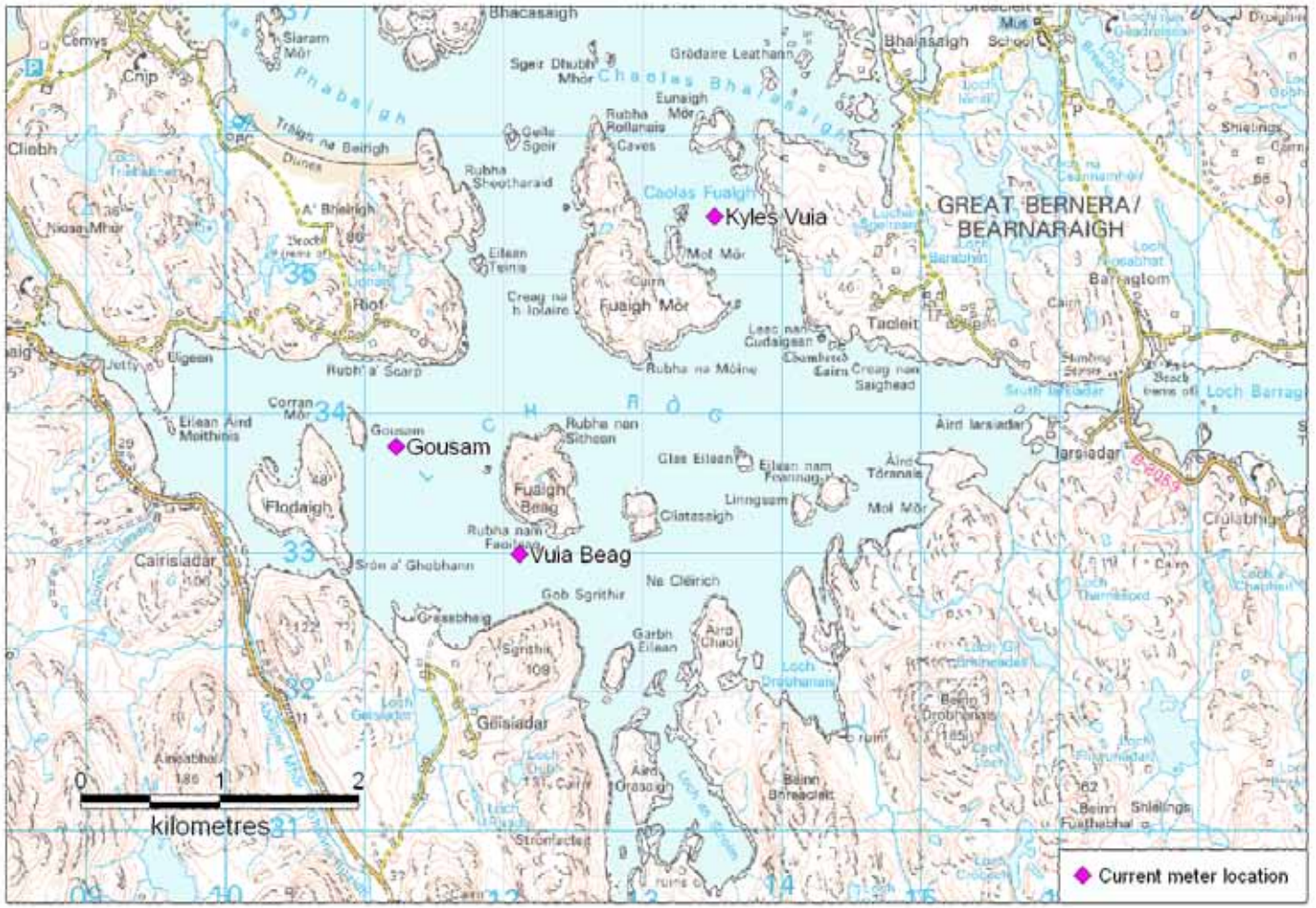

Figure 14.3 Current meter locations

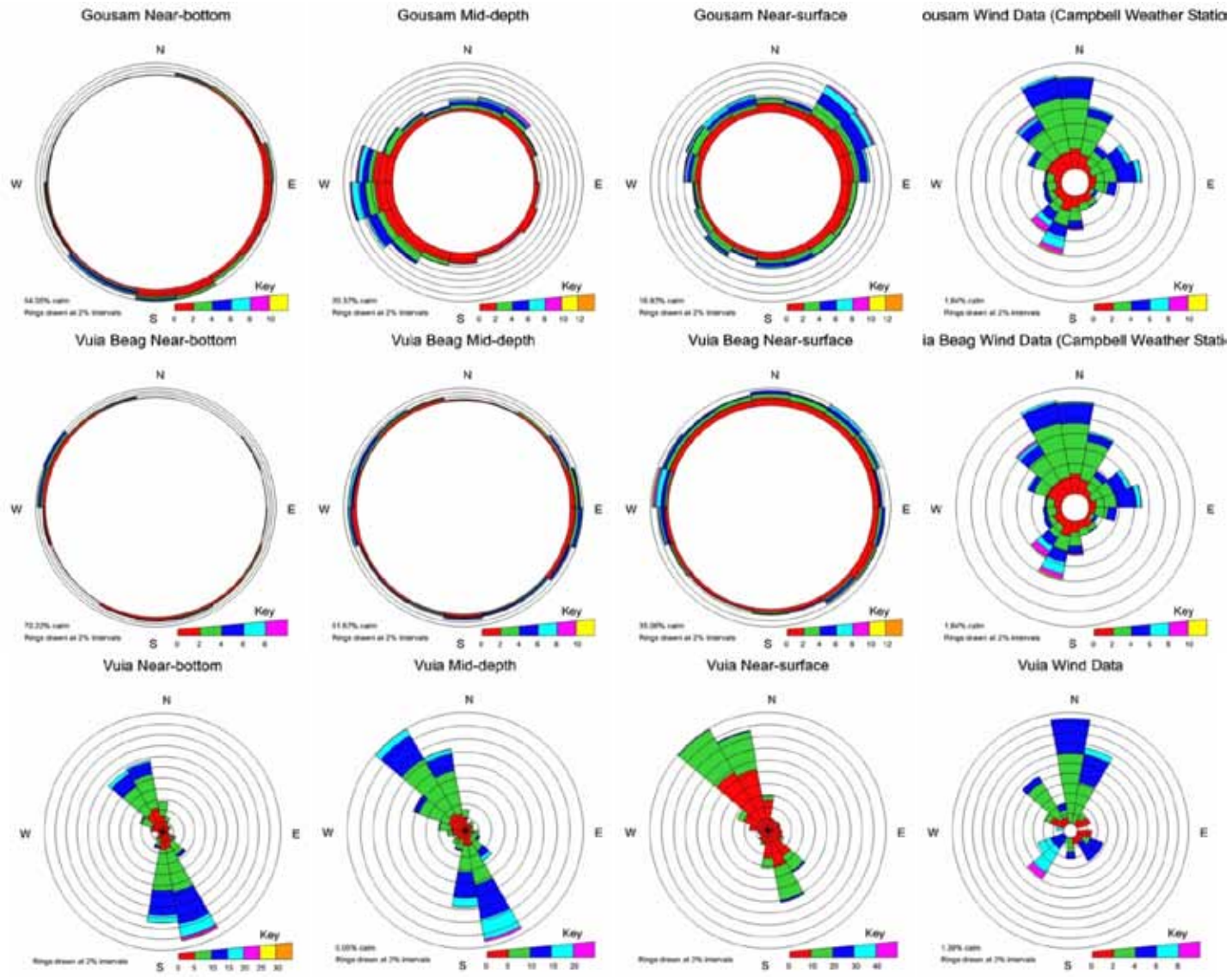

Figure 14.4 Current plots for Loch Roag

Figure 14.5 Salinity profile location

15. Shoreline Survey Overview

A shoreline survey was conducted on 18th, 19th and 21st July 2011 under predominantly rainy conditions.

The mussel fishery consisted of five double-headed long lines oriented roughly north to south, east of Aird Meinish, just outside Loch Miabhaig. Droppers nearest the shore extend to 6 metres depth and all others to 8 metres. Most of the lines had been recently harvested. The northern end of the westernmost line had mature stock of sufficient size from which a sample was taken.

None of the dwellings adjacent to the fishery were on mains sewerage; most homes in the area appeared to be on soakaway systems. Only a small number of septic tank outlets were noted at the shoreline but only one was flowing at the time of the survey. A significant number of the homes in the area are in seasonal occupation, either as holiday homes or self-catering rentals. There are no hotels or campsites in the vicinity.

Land in the area is used for extensive livestock rearing and crofting. Sheep are grazed throughout the area and sheep droppings were observed around much of the shoreline. A total of 338 sheep and 14 cattle were observed. Small numbers of other livestock such as pigs, ducks and chickens were kept at some of the crofts. No arable farming was observed adjacent to the loch.

Geese and small numbers of seabirds were observed during the survey. Although no deer were observed on the shoreline, they were seen along the road on the way to the survey site. Some of the droppings observed may have been from deer.

A number of mostly small open boats are kept in Loch Miabhaig. Small pleasure craft, RIBs and fishing boats as well as a larger tour boat are kept at Miavaig pier. On the day of survey,16 small boats, 3 larger fishing boats present and 8 empty moorings were seen. Further east in the loch, there is a salmon farm shore base at the pier and a tour boat operator. The tour operator runs trips approximately from the beginning of May to the end of September.

A number of small streams and areas of direct runoff from land were observed. Larger streams or burns discharged to the head of Loch Miabhaig and to the south shore south of the fishery. Most of the watercourses were running at the time of survey. However, after three days with no rain the flow in the Abhainn Mhòr a' Ghlinne Ruaidh, the largest of the observed watercourses, appeared to diminish markedly. This suggested that flow in many of the watercourses feeding into the loch may drop sharply during periods of dry weather.

Results for *E. coli* in water ranged from <100 to 90000 for freshwater samples and from 2 to 1400 in seawater samples. All water samples containing >1000 *E. coli*/100 ml were collected from sources along the north shore. Salinities

recorded for the seawater samples ranged from 31.8 to 37.4. The two mussel samples, collected from a rope on the mussel farm and from the shore at the head of Loch Miabhaig, both returned results of <20 *E. coli*/100 g, suggesting that the mussels at these locations were not significantly contaminated despite the high concentrations of *E. coli* found in water in the vicinity.

Figure 15.1 shows a map of the most significant findings from the shoreline survey.

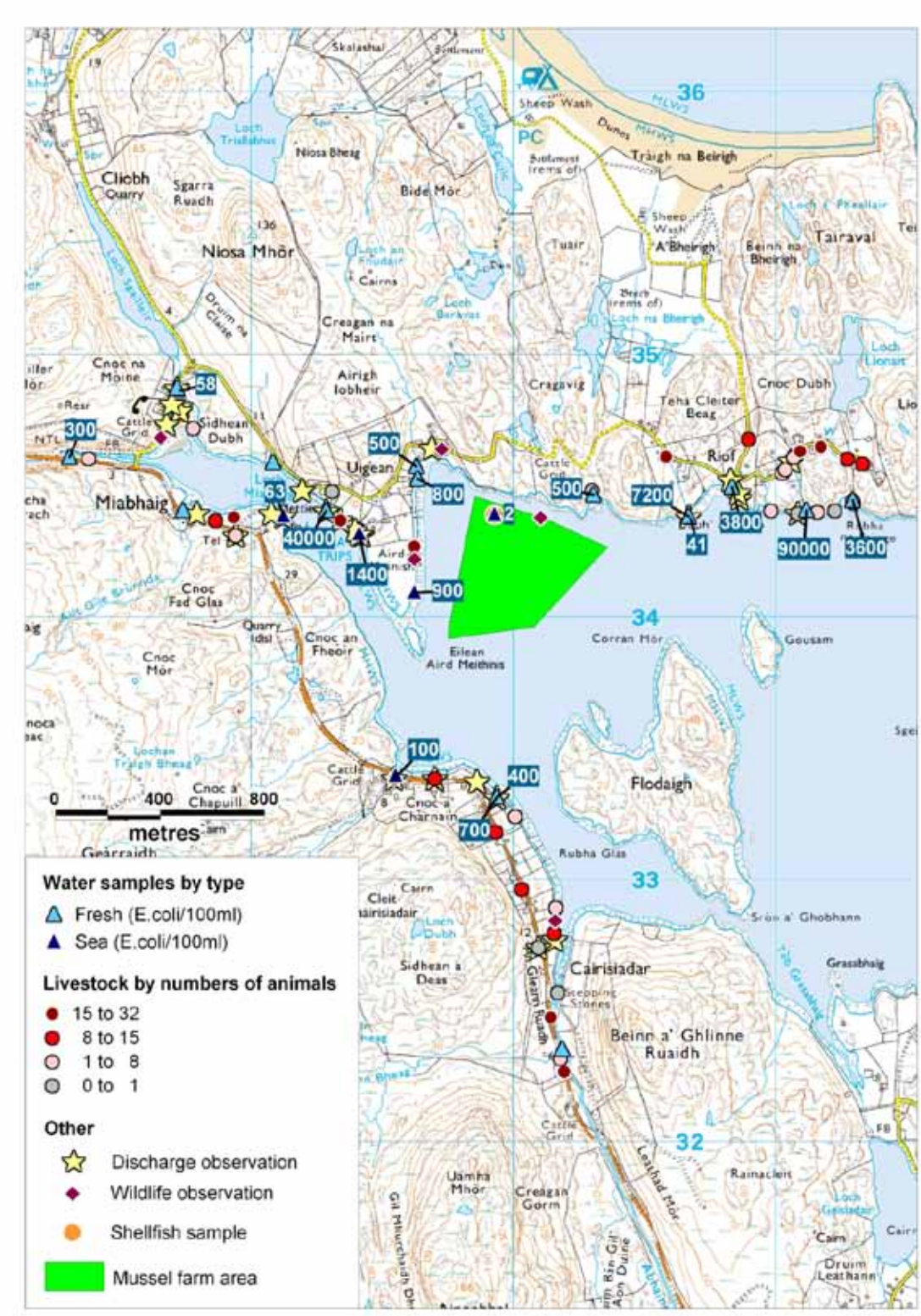

Figure 15.1 Summary of shoreline survey findings for Loch Roag: Miavaig

16. Overall Assessment

Human sewage impacts

There is no mains sewerage provision for properties adjacent to Loch Miabhaig or Miavaig Bay. The majority of dwellings have private septic tanks discharging to soakaway systems. The concentrations of homes at Riof, the north shore of Loch Miabhaig and north of Cairisiadar coincide with areas of soils classed as freely draining, suggesting that properly maintained soakaways in these areas should not materially impact on water quality at the fishery. Septic tanks found around Loch Miabhaig, Riof and along the road north of Cairisiadar do discharge either to the streams or directly to the waters of the loch and these are likely to affect water quality in the vicinity. A church at the head of the loch and facilities at Miavaig pier are likely to contribute the largest discharges in terms of volume, though no information about the discharge from the shore base at the pier was available. Two fresh water samples and an outfall water sample taken during the shoreline survey contained concentrations of *E. coli* that suggest some sewage input. One of these related to the unnamed tributary to which an identified septic tank was consented to discharge. This entered the loch approximately 300 metres east of the mussel farm. A second stream was located 450 metres further east, and a spot sample was found to contain 90000 *E. coli* cfu/100 ml. This is higher than we have normally seen in streams with diffuse pollution from livestock, and was located near a reported septic tank. The third sample came from a flowing discharge pipe 720 metres west of the mussel farm, and this was found to contain 40000 *E. coli* cfu/100 ml. These sources are the most likely to impact at the fishery, and overall the easternmost corner of the mussel farm lies nearest to sources discharging to water.

Agricultural impacts

No arable farming was observed around the loch. Livestock are grazed throughout the area and sheep droppings were observed around much of the shoreline. A total of 338 sheep, 14 cattle and 3 pigs were seen during the shoreline survey, with the largest concentrations of animals found at Riof and on land west of the fishery. Further livestock were recorded around Miavaig and along the B8011 between Miavaig and Cairisiadar.

Streams with high faecal loadings are likely to carry diffuse contamination from livestock as well as other sources. During periods of heavy rain, runoff from land at these locations is likely to wash faecal material from the hillsides into the loch and any impact on the fishery is most likely to affect the lines nearest the shore and near to where streams carry land runoff to the loch.

Wildlife impacts

Wildlife species in and around Loch Roag are likely to have a limited impact on bacteriological quality of water around the fishery due to the relatively small number of animals likely to be present compared with the large and open water area of the outer loch. Seals, seabirds and waterfowl may

potentially directly deposit faeces to waters at the mussel farm, though this is likely to be limited in extent and duration and relatively unpredictable.

Faecal contamination from waterfowl and deer is likely to be present in runoff discharging to the loch, and therefore impacts from these sources would be higher near where streams and other freshwater runoff enters the loch. Impacts from this source are likely to be higher nearer the surface of the lines and at the northeast and northwest ends of the fishery, where grassland areas are likely to be grazed by geese and deer.

Seasonal variation

A number of parameters that will influence the flux of faecal indicator bacteria to the waters around the fishery show seasonal variation. Rainfall was seen to be highest during autumn and winter, and a higher occurrence of northeasterly winds is seen during spring and summer. Winds are generally lightest in summer and strongest in winter.

There is some increase in human population during the summer tourist season, though this could not be quantified. Some of the homes in the area are only seasonally occupied. Tour boats operate from Miavaig pier from mid-April until the end of September, though peak visitor numbers generally occur in July and August.

Livestock numbers are likely to be highest in summer, when lambs are present, and drop again in autumn when they are sent to market. Animals will tend to be kept on or near to croft areas and so distributions may not vary markedly from those observed during the survey.

Historical monitoring results tended to be lower in the early part of the year, with lowest results tending to occur in April and May and highest results between August and November. Analysis of results by season identified that results in spring were significantly lower than in summer and autumn and that results in winter were significantly lower than in autumn.

Rivers and streams

The watercourses identified and sampled represent potential sources of contamination to the mussel lines, In general, the estimated loadings for the sampled and measured watercourses were moderate and, under similar rainfall conditions, would be expected to impact on the water quality in the area.

The two streams located near Uigean have the potential to directly impact on the microbiological quality of the mussels at the north-western corner of the lines. The watercourses on the outer northern shore (including the Riof area) will potentially impact on the northern part of the lines while those located within Loch Miabhaig will generally add to the contamination levels within the outer area during an ebb tide and may specifically impact on the south-western corner of the lines.

A highly significant correlation was found between *E. coli* result and rainfall in the previous 2 days and 7 days. However, the highest results were seen after moderate amounts of rainfall (approximately 20 mm) and the effect with rainfall appeared therefore to be due primarily to the absence of low recorded results after increasing rainfall, rather than the absence of high results at low rainfall levels. This suggests that even small amounts of rainfall may mobilise contaminants from land-based sources. However, the fact that results > 230 MPN/100g were found after no recorded rainfall suggests that not all significant sources are rainfall dependent.

Movement of contaminants

Predicted tidal flows for the Sound of Vuia are relatively weak, and currents measured within the area of west Loch Roag were also generally weak and tended to flow to the north and northeast over much of the tidal cycle. Current flows in the vicinity of the mussel lines are likely to run parallel to shore. Although the weak current speeds suggest wind-driven flows are likely to be significant, no evidence of a wind-driven component to flow was seen in current and wind data from fish farm assessments.

Within Miavaig Bay, south-westerly winds may tend to increase the effects of the ebb tide and reduce the effect of the flood tide. However, there was no indication of wind effects in the current data analyses.

On the ebb tide, the north-west corner of the lines will be exposed to contamination arising in the vicinity of Uigean while the south-west corner of the lines may be exposed to contamination coming out of Loch Miabhaig. However, the latter effect may be reduced because of the drying channel between Aird Meinish and Eilean Aird Meinish: once this is exposed, flows will be diverted round the southern end of the island and away from the fishery. On the flood tide, the north-eastern corner of the lines may be exposed to contamination arising from the area around Riof.

No significant correlation was found between monitoring results and the spring/neap tidal cycle, however a significant effect was found with the high/low tidal cycle. Higher results tended to occur around high water and over the first half of ebb tide, suggesting that sources to the east of the fishery may be more significant. This correlation also suggests that these source may be more consistent in nature and therefore not necessarily dependent on rainfall. The highest result was seen in a sample taken around low tide, however. This could have been due to sources to the west or localised sources that are not tidally dependent, such as direct deposition near the fishery by wildlife or overboard discharges from boats.

Temporal and geographical patterns of sampling results

Analysis of historical data shows no clear change in the underlying level of *E. coli* contamination in the fishery over the five year period considered.

Geographic assessment of monitoring results identified that there was a tendency for higher results in samples taken from locations within a band

across the eastern side of the fishery from Eilean Aird Meithinis to Rubh' a' Scarp.

Conclusions

A mix of both human and agricultural sources are likely to affect water quality at the fishery, with a seasonal increase in human and livestock populations coinciding with a seasonal increase in *E. coli* monitoring results at the fishery.

The mix of significant correlations with rainfall and with the high/low tidal cycle suggests that two pathways of contamination are present at this fishery: one rainfall dependent and one independent of rainfall. The association of higher results overall with high tide and the first part of the ebb tide suggests a source east of the fishery that is not dependent on rainfall. This seems to concur with the presence of sewage discharges from properties at Riof.

As was observed during the shoreline survey, many of the watercourses quickly subside and dry up after even short periods of no rainfall. This suggests that the pathway for diffuse contamination will be tightly correlated to rainfall, which corresponds with what was seen in historical monitoring results.

Only small numbers of wildlife were observed during the survey and these are expected to make only a minor contribution to background levels of contamination at the fishery. The area most likely to be impacted by the sources identified is the eastern side of the fishery, as is suggested by the trend toward higher results there. Considering the predicted movement of contaminants, sources closest to the fishery are more likely to have an effect and therefore the northeastern end of the mussel farm may be most affected.

17. Recommendations

Production area

It is recommended that the production area be amended to exclude potential sources of faecal contamination up-loch and along the south shore and to include the entire recorded mussel line area plus a small buffer for movement of the lines. Although there are livestock along the shoreline immediately north and west of the fishery, the Crown Estate lease for the mussel farm extends to the shore and so the production area is extended to MHWS along this boundary.

The recommended boundaries are described as the area bounded by lines drawn between NB 0957 3400 and NB 0956 3350 and between NB 0956 3350 and NB 1029 3367 and between NB 1029 3367 and NB 1042 3437 and extending to MHWS.

RMP

It is recommended that the RMP be relocated to NB 1028 3424 to reflect the larger sources of contamination to the east at Riof. This is also in the line across the fishery where historical samples have yielded the highest results.

Tolerance

A standard tolerance of 40 metres is recommended for this area to allow for some movement of the mussel lines.

Depth of sampling

No evidence regarding variation in *E. coli* with depth was obtained for this area. Therefore a standard sampling depth of 1-3 metres is recommended.

Frequency

As significant seasonal variation was seen in the sampling results, it is recommended that sampling be undertaken on a monthly basis.

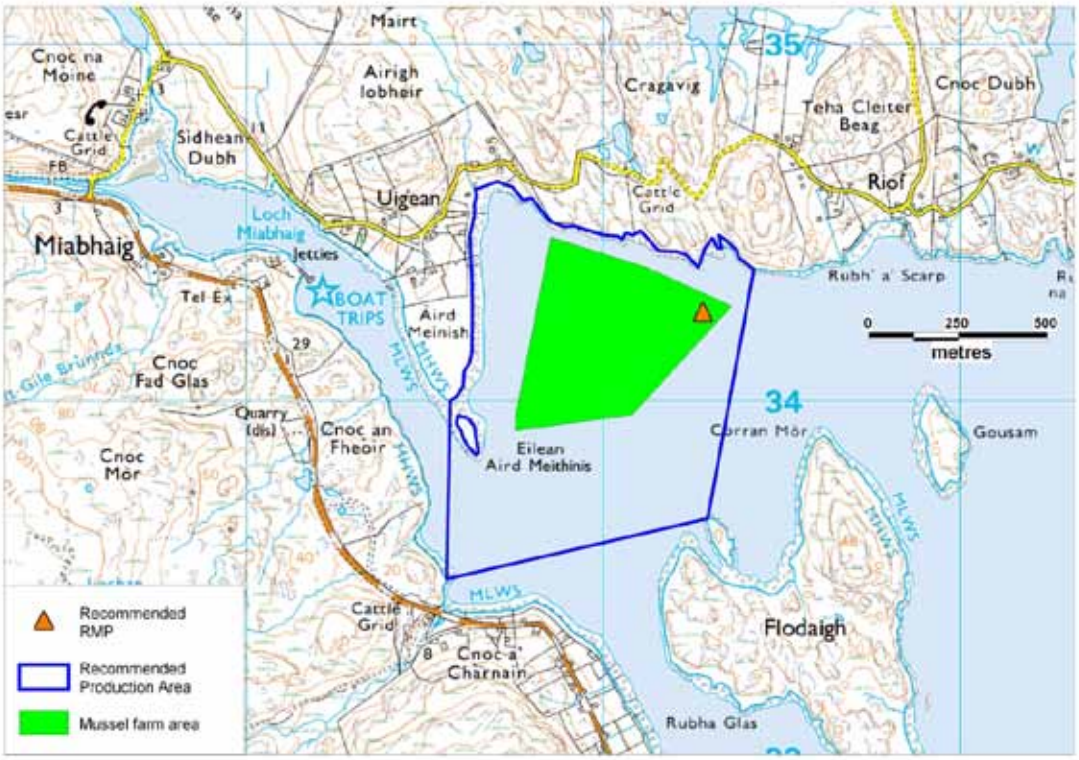

Figure 17.1 Map of recommendations at Loch Roag: Miavaig

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19. List of Figures and Tables

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1. **Geology and Soils Assessment Method**
2. **General Information on Wildlife Impacts**
3. **Tables of Typical Faecal Bacteria Concentrations**
4. **Statistical Data**
5. **Hydrographic Methods**
6. **Shoreline Survey Report**

Geology and Soils Assessment Method

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website

and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

Both bacterial and viral pathogens affecting humans and livestock have been found in wild and captive seals. *Salmonella* and *Campylobacter* spp., some of which were antibiotic-resistant, were isolated from juvenile Northern elephant seals (*Mirounga angustirostris*) with *Salmonella* found in 36.9% of animals stranded on the California coast (Stoddard et al 2005). *Salmonella* and *Campylobacter* are both enteric pathogens that can cause acute illness in humans and it is postulated that the elephant seals were picking up resistant bacteria from exposure to human sewage waste.

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales. Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin

faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

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Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	150	1.9×10^9

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Statistical Data

One-way ANOVA: Log_EC versus Season

```
Source  DF      SS     MS     F      P
Season   3   9.464  3.155  9.62  0.000
Error   52  17.051  0.328
Total   55  26.515

S = 0.5726   R-Sq = 35.69%   R-Sq(adj) = 31.98%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  ---+---------+---------+---------+------
1      15  1.1238  0.2608  (----*-----)
2      14  1.7885  0.7138              (-----*-----)
3      14  2.2309  0.6830                      (------*-----)
4      13  1.4933  0.5330        (------*-----)
                          ---+---------+---------+---------+------
                           1.00      1.50      2.00      2.50

Pooled StDev = 0.5726


Grouping Information Using Tukey Method

Season   N    Mean  Grouping
3       14  2.2309  A
2       14  1.7885  A B
4       13  1.4933    B C
1       15  1.1238      C

Means that do not share a letter are significantly different.


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.94%

Season = 1 subtracted from:

Season    Lower  Center   Upper  -------+---------+---------+---------+--
2        0.1005  0.6647  1.2290                    (------*------)
3        0.5428  1.1070  1.6713                          (------*------)
4       -0.2059  0.3695  0.9448                (-------*------)
                                -------+---------+---------+---------+--
                                    -0.80      0.00      0.80      1.60


Season = 2 subtracted from:

Season    Lower   Center   Upper  -------+---------+---------+---------+--
3       -0.1316   0.4423  1.0162                (-------*------)
4       -0.8801  -0.2952  0.2896        (------*-------)
                                -------+---------+---------+---------+--
                                    -0.80      0.00      0.80      1.60


Season = 3 subtracted from:

Season    Lower   Center    Upper  -------+---------+---------+---------+--
4       -1.3224  -0.7376  -0.1527  (-------*------)
                                  -------+---------+---------+---------+--
                                      -0.80      0.00      0.80      1.60
```

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

Background processes

Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

In sea lochs, mechanisms such as "wind rows" can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

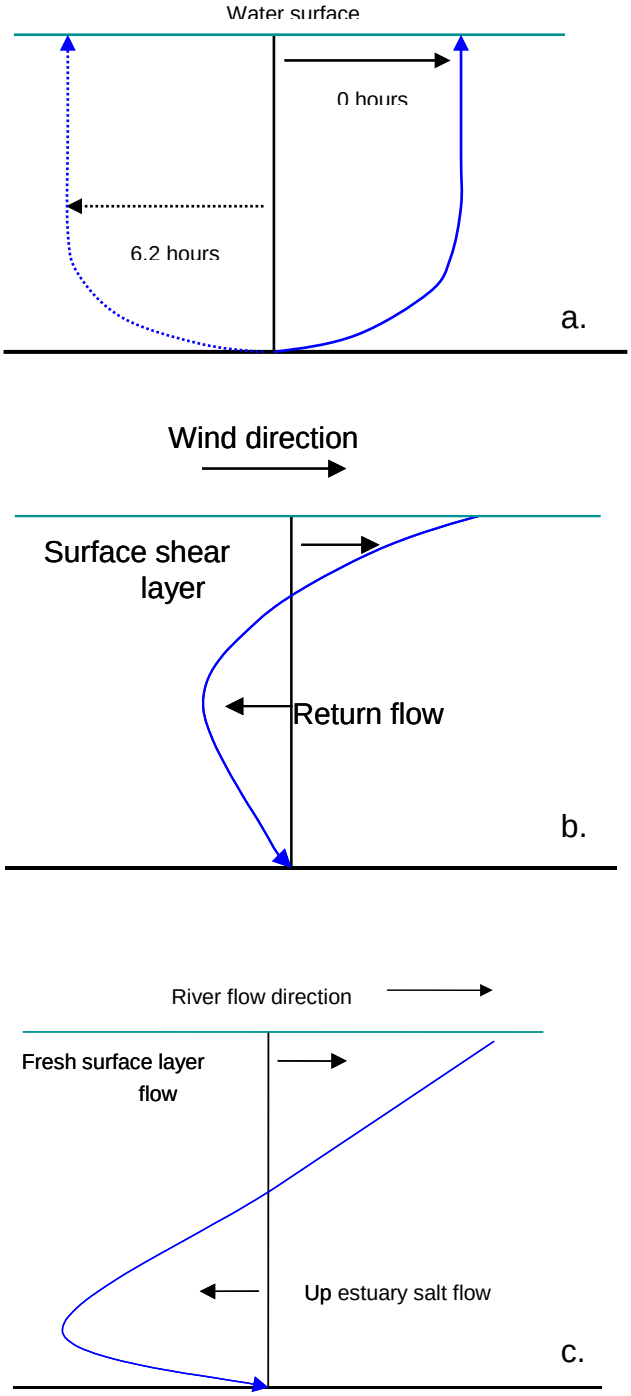

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

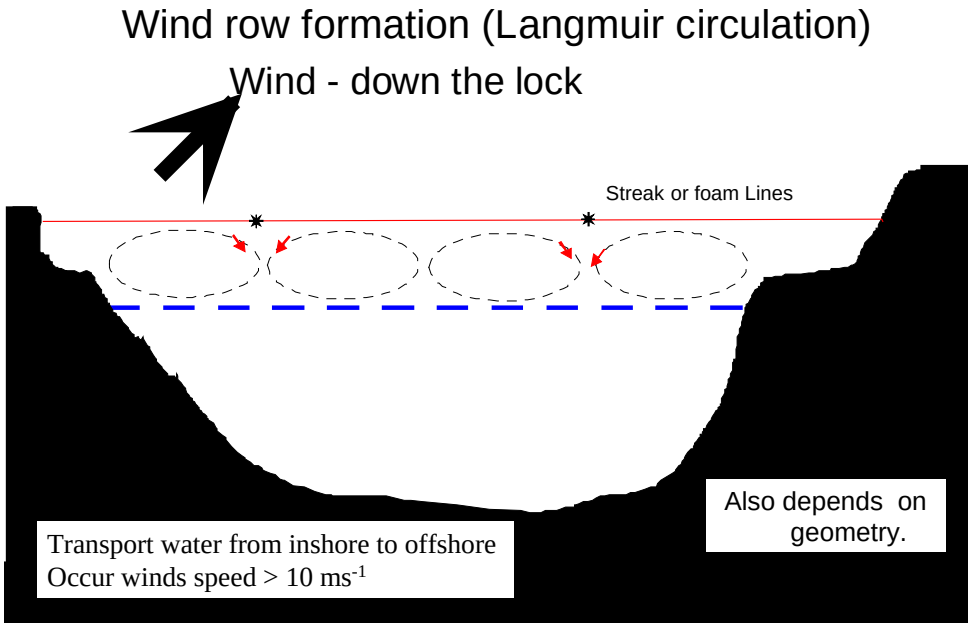

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill

area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

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Glossary

The following technical terms may appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.

Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.

Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

Shoreline Survey Report

Prod. area:	East Loch Roag - Miavaig
Site name:	Miavaig (LH 188 123 08)
Species:	Common mussel
Harvester:	Cree Mackenzie/Calum Ian Mackenzie
Local Authority:	Comhairle nan Eilean Siar
Status:	Existing
Date Surveyed:	18-19, 21 July 2011
Surveyed by:	Michelle Price-Hayward, Ron Lee
Nominal RMP:	NB 118 349
Area Surveyed:	Loch Miavaig, north shore to Riof, and Cairisiadar

Weather observations

18 July. Cloudy/misty, rain, winds N to NW F3-4, Temp 13C. Heavy rain overnight and previous day.

19 July. Heavy rain overnight. Overcast. Light rain and mist, winds N F4-5, Temp. 12C.

21 July. Dry, partly cloudy, winds N F2-3 Temp 10C.

Site Observations

Fishery

The Miavaig mussel fishery is comprised of 5 double-headed longlines oriented roughly N-S to the east of Aird Meinish, just outside Loch Miavaig in Loch Roag. Droppers nearest the shore extend to 6 meters depth and all others to 8 meters.

Most of the lines had been recently harvested at the time of survey. Only the northern end of the westernmost line had mature stock of sufficient size and therefore a sample was taken from this area.

Sewage/Faecal Sources

None of the dwellings adjacent to the fishery were on mains sewerage. A discharge pipe was found below a septic tank for a church near the head of the loch, though there was very little flow at time of survey. There were a fish farm base and a tourist boat operator at the pier near the head of the loch, and a septic tank outlet pipe was observed but also not flowing at the time of survey. Septic tank discharges to shore were found along the shores of Loch Miavaig and at Cairisiadar, and one septic tank could be seen to discharge to the Abhainn Uasaig where it pooled up against the fill for the road. However, most homes in the area appeared to be on soakaway systems.

Farming and livestock

Sheep are grazed extensively throughout the area and sheep droppings were observed around much of the shoreline. A total of 338 sheep were observed, though the terrain was rough and could have obscured an unknown additional number of animals. Cattle were present (14 observed) in much lower numbers than the sheep. Small numbers of other livestock such as pigs, ducks and chickens were kept at some of the crofts. No arable farming was observed adjacent to the loch.

Seasonal Population

A number of the homes in the area are in seasonal occupation, either as holiday homes or self-catering rentals. There are no hotels or campsites in the vicinity.

Boats/Shipping

A number of mostly small open boats are kept in Loch Miavaig. Small pleasure craft, RIBs and fishing boats as well as a larger tour boat are kept at Miavaig pier. On the day of survey, there were 16 small boats, 3 larger fishing boats present and 8 empty moorings. Further to the east along the loch, There is a salmon farm shore base located at the pier, as well as a tour boat operator. The tour operator runs trips from roughly the beginning of May through the end of September.

Land Use

Land in the area is used for extensive livestock rearing and crofting. A significant number of the dwellings in the area are used for holiday accommodation.

Land Cover

Land in the area is used for extensive livestock rearing and crofting. A significant number of the dwellings in the area are used for holiday accommodation.

Watercourses

A number of small streams and areas of direct runoff from land were observed. Larger streams or burns discharged to the head of Loch Miavaig and to the south shore south of the fishery.

Most of the watercourses were running at the time of survey. However, after three days with no rain the flow in the Abhainn Mhòr a' Ghlinne Ruaidh, the largest of the observed watercourses, appeared to diminish markedly though this was not measured.

Wildlife/Birds

Geese and small numbers of seabirds were observed during the survey. Although no deer were observed on the shoreline, some of the droppings observed may have been from deer and deer were observed along the road on the way to the survey site.

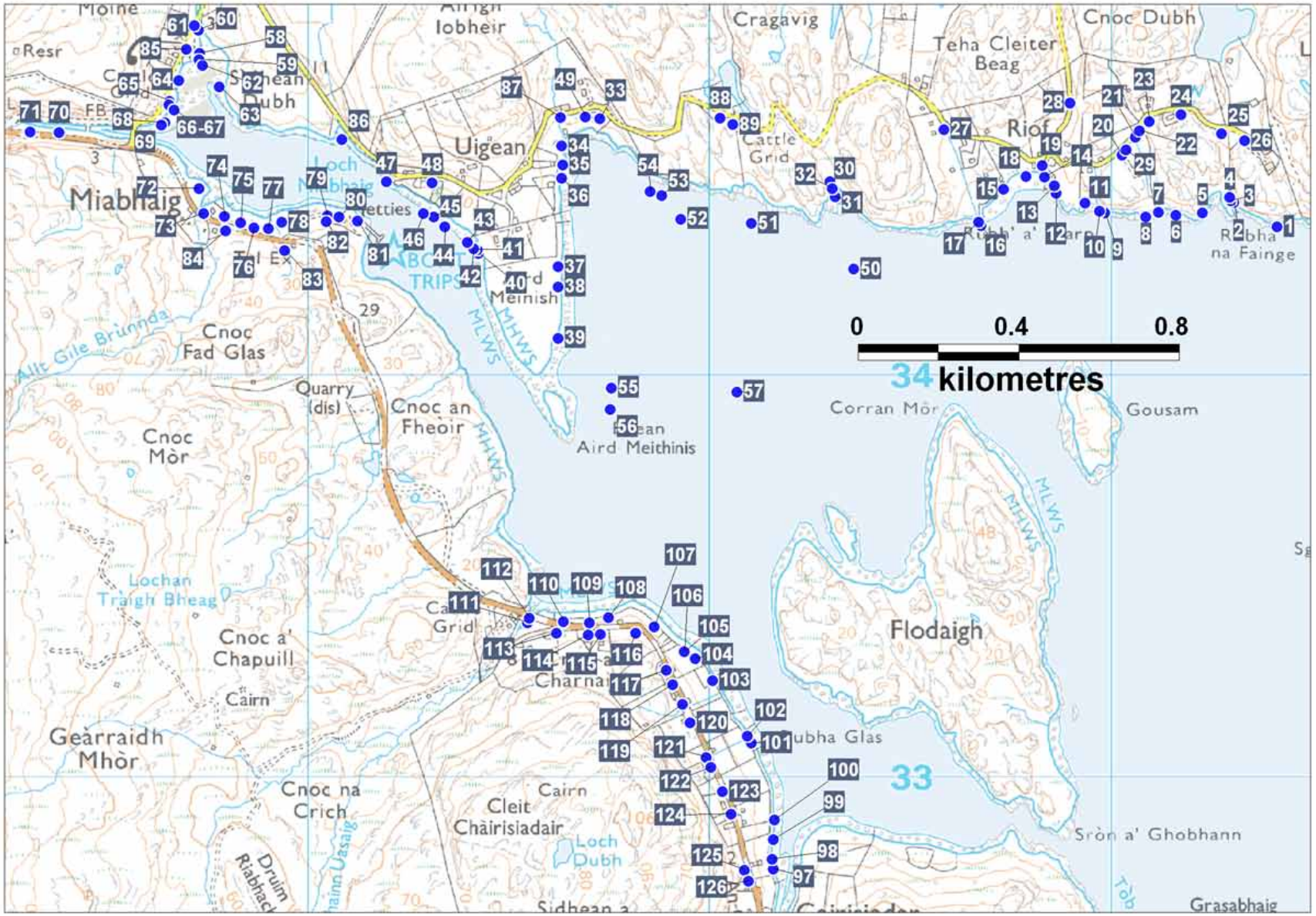

Figure 1. Map of survey observations - Miavaig

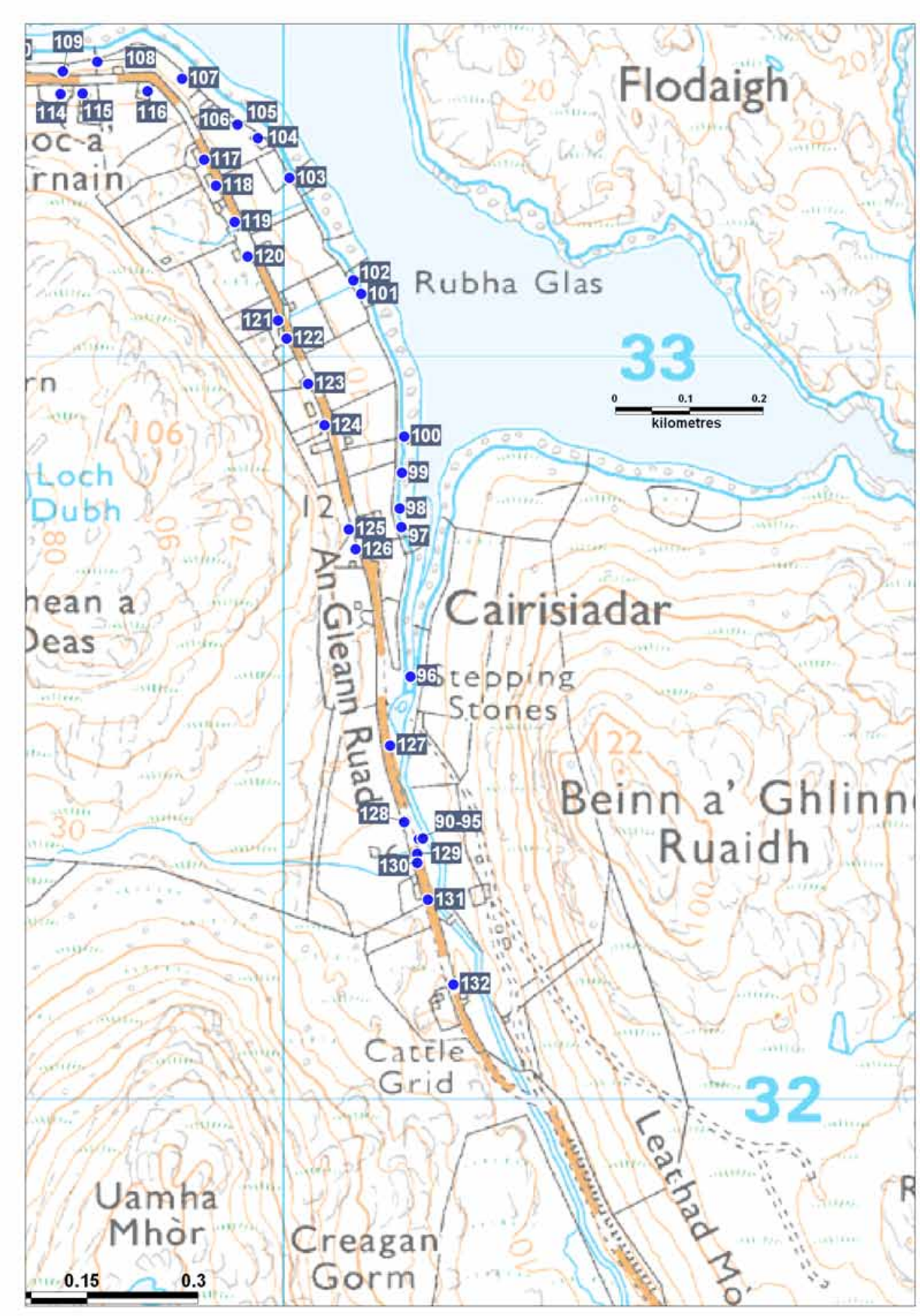

Figure 2. Map of survey observations - Cairisiadar

Figure 2. Map of survey observations - Cairisiadar

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
1	18/07/2011	08:14:42	NB 11413 34370	111413	934370		No evidence of discharge pipes at shore, salmon farm just offshore, land cover heath
2	18/07/2011	08:25:28	NB 11305 34431	111305	934431		Small stream running under vegetation and dropping through rocks to shore here, no measurement or sample
3	18/07/2011	08:28:44	NB 11298 34436	111298	934436		Sheep droppings
4	18/07/2011	08:30:04	NB 11295 34444	111295	934444		Stream: 40 cm x 5 cm, flow 0.399 m/s, SD 0.005. Water sample LRMW1. Hoof prints along stream, plastic and other waste washed up on shore, old row boat
5	18/07/2011	08:43:24	NB 11227 34405	111227	934405		Other end of bay, marshy with land runoff and sheep droppings along the shore between these points
6	18/07/2011	08:46:44	NB 11161 34400	111161	934400		Many sheep droppings, 2 sheep in view up hill from shore
7	18/07/2011	08:49:20	NB 11118 34406	111118	934406		Stream: 20 cm x 3 cm, flow 1.039 m/s, SD 0.027. Water sample LRMW2
8	18/07/2011	08:57:41	NB 11086 34395	111086	934395		House, presumed to be on septic tank. No pipe to shore evident. Although the field is fenced from the shore, sheep droppings were frequent along the shore side of the fence
9	18/07/2011	09:04:38	NB 10984 34405	110984	934405		2 sheep seen up the hill and to the west, on opposite side of stream in 11
10	18/07/2011	09:05:57	NB 10972 34410	110972	934410		Small stream, houses uphill. Appears to be drainage runoff rather than permanent stream. Not measured or sampled
11	18/07/2011	09:08:50	NB 10936 34429	110936	934429		Small stream, gravel bed so may be permanent. Not measured or sampled
12	18/07/2011	09:20:35	NB 10864 34454	110864	934454	Figure 4	End of ceramic pipe, no apparent flow - no sewage fungus, though a strip of bright green algae on seabed
13	18/07/2011	09:23:12	NB 10859 34473	110859	934473	Figure 5	Septic tank, discharge pipe leading downward, but no outfall pipe visible from shore
14	18/07/2011	09:28:26	NB 10834 34494	110834	934494		Stream: 30 cm x 8 cm, flow 0.470 m/s, SD 0.011. Water sample LRMW3. Green algae growing on seabed where stream discharges. Small numbers of mussel and cockle shells on shore
15	18/07/2011	09:38:34	NB 10732 34464	110732	934464		Small stream, shore marshy here, houses up hill along stream. Not measured or sampled
16	18/07/2011	09:45:31	NB 10677 34373	110677	934373		Water sample LRMW4, seawater sample
17	18/07/2011	09:49:50	NB 10670 34382	110670	934382		Stream: 22 cm x 7 cm, flow 0.0302 m/s, SD 0.006. Water sample LRMW5. Houses upstream
18	18/07/2011	10:00:34	NB 10788 34496	110788	934496		Small, shallow stream adjacent to house. Not measured or sampled. Marshy land with much drainage between points 15 and 19

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
21	18/07/2011	10:09:56	NB 11061 34594	111061	934594		Concrete septic tank with small diameter pipe overflow to land/ditch - not flowing
22	18/07/2011	10:10:42	NB 11071 34609	111071	934609		4 cattle in field on land side of road
23	18/07/2011	10:11:41	NB 11095 34633	111095	934633		Home with 23 sheep in field behind it
24	18/07/2011	10:14:09	NB 11174 34650	111174	934650		27 sheep
25	18/07/2011	10:16:17	NB 11275 34603	111275	934603		8 sheep
26	18/07/2011	10:17:23	NB 11333 34585	111333	934585		8 sheep
27	18/07/2011	10:25:35	NB 10584 34613	110584	934613		Farm on the shore side of road with 32 sheep
28	22/07/2011	16:58:48	NB 10898 34679	110898	934679		10 cattle east of the road
29	22/07/2011	17:04:32	NB 11038 34562	111038	934562		3 pigs
30	18/07/2011	10:32:31	NB 10301 34483	110301	934483		Cattle droppings
31	18/07/2011	10:34:06	NB 10313 34446	110313	934446	Figure 6	View of mussel farm line from shore
32	18/07/2011	10:37:47	NB 10306 34465	110306	934465		Stream that splits into two forks just before shore, measured above fork. 55 cm x 6 cm, flow 0.092 m/s, SD 0.007. Water sample LRMW6
33	18/07/2011	10:56:16	NB 09728 34640	109728	934640		House, 15 ducks, sheep droppings.
34	18/07/2011	11:03:09	NB 09632 34572	109632	934572	Figure 7	Stream: 100 cm x 12 cm, flow 1 - 0.636 m/s SD 0.044 flow 2 - 0.240 m/s SD 0.026. Water sample LRMW7. Rain
35	18/07/2011	11:10:44	NB 09636 34525	109636	934525		Stream: 31 cm x 3 cm, flow 0.060 m/s, SD 0.007. Water sample LRMW8
36	18/07/2011	11:15:12	NB 09633 34491	109633	934491		Seepage from land
37	18/07/2011	11:25:32	NB 09624 34271	109624	934271		19 sheep in field
38	18/07/2011	11:26:29	NB 09624 34221	109624	934221		Boggy ground, sheep and grouse droppings
39	18/07/2011	11:29:17	NB 09624 34093	109624	934093		Water sample LRMW9, seawater
40	18/07/2011	11:38:53	NB 09426 34304	109426	934304		Ridge under grass in line with rock groin on shore
41	18/07/2011	11:39:43	NB 09422 34313	109422	934313		Iron pipe sticking up from ground. Foul odour in air
42	18/07/2011	11:41:16	NB 09414 34316	109414	934316	Figure 8	Ceramic septic pipe, appears to be connected, runs under shore, no outlet found. Water sample LRMW10, seawater taken offshore of pipe
43	18/07/2011	11:47:50	NB 09398 34331	109398	934331		Sewage fungus on shore
44	18/07/2011	11:51:47	NB 09342 34370	109342	934370		2 horses on adjacent shore. 22 sheep in view on opposite shore. 1 yacht plus 4 open boats on moorings, angling and fishing, small boats at pier
45	18/07/2011	11:57:41	NB 09315 34395	109315	934395		Seepage from land across shore
46	18/07/2011	11:59:11	NB 09288 34404	109288	934404		Land runoff and septic tank outfall. Water sample LRMW11
47	18/07/2011	12:11:16	NB 09196 34483	109196	934483		Foul odour
48	18/07/2011	12:20:43	NB 09310 34480	109310	934480		Sheep, sound of running water, on shore side of road
49	18/07/2011	12:27:47	NB 09691 34644	109691	934644		Rock on ST cover downhill from road. Mussel farm in view from shore

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
50	19/07/2011	10:02:07	NB 10360 34265	110360	934265		Miavaig - 5 double-headed longlines, droppers to 6 m at shallowest line, 8 m at all others. Corner of farm
51	19/07/2011	10:04:10	NB 10105 34379	110105	934379		Fences on adjacent shore begin at about this point. 5 oystercatchers, one feeding on line adjacent to float
52	19/07/2011	10:05:51	NB 09929 34390	109929	934390		Mussel sample Miavaig 1. Water sample LRMW12
53	19/07/2011	10:13:48	NB 09881 34449	109881	934449		Corner of mussel farm (taken approximately at anchor float)
54	19/07/2011	10:14:31	NB 09853 34458	109853	934458		Salinity profile: 5m - 35.6 ppt/13.6C. 3m - 35.6 ppt/13.6C. 1m - 35.6 ppt/13.6C. Surface 35.5 ppt/13.6 ppt
55	19/07/2011	10:19:50	NB 09757 33969	109757	933969		Corner of mussel farm (taken approximately at anchor float)
56	19/07/2011	10:20:05	NB 09753 33916	109753	933916		Corner of mussel farm (taken approximately at anchor float)
57	19/07/2011	10:21:32	NB 10069 33959	110069	933959		Corner of mussel farm (taken approximately at anchor float)
58	21/07/2011	06:10:35	NB 08732 34803	108732	934803	Figure 9	Discharge pipe below church. Very slight flow
59	21/07/2011	06:13:25	NB 08730 34786	108730	934786	Figure 10	Old septic tank, outlet/overflow pipe dry and did not appear recently used
60	21/07/2011	06:20:31	NB 08729 34860	108729	934860		Culverted stream from Loch Sgailleir, pipe diameter 110 cm, wetted surface 80 cm, depth at centre 10 cm, flow 0.176 m/s, SD 0.012. Water sample LRMW13
61	21/07/2011	06:25:39	NB 08719 34871	108719	934871		Pipe running into culvert, end not visible, upstream of sample LRMW14
62	21/07/2011	06:31:00	NB 08739 34772	108739	934772		Mussel sample Miavaig 2. Shore mussels on rocks and seabed
63	21/07/2011	06:36:18	NB 08781 34719	108781	934719		2 sheep on shore
64	21/07/2011	06:46:43	NB 08679 34735	108679	934735	Figure 11	Outfall pipe, iron, below house. No flow apparent
65	21/07/2011	06:51:04	NB 08656 34683	108656	934683		Possible deer droppings
66	21/07/2011	06:51:26	NB 08655 34674	108655	934674		Surface water culvert
67	21/07/2011	06:53:10	NB 08668 34661	108668	934661		Large amounts of iron and other debris on shore
68	21/07/2011	06:54:31	NB 08645 34629	108645	934629		Large numbers of shore mussels on rocks and seabed
69	21/07/2011	06:56:36	NB 08637 34624	108637	934624		Surface water pipe, dribbling. Not sampled
70	21/07/2011	07:03:09	NB 08381 34605	108381	934605		1 sheep
71	21/07/2011	07:08:10	NB 08309 34607	108309	934607		Abhainn a' Ghlinne: 170 cm x 26 cm. Flow 0.183 m/s, 0.033 SD. Water sample LRMW15
72	21/07/2011	07:19:23	NB 08730 34466	108730	934466		Floating jetty/walkway anchored in loch
73	21/07/2011	07:23:40	NB 08741 34404	108741	934404		Allt Gile Brùnnda: 25 cm x 8 cm. Flow 0.168, SD 0.004. Water sample LRMW16
74	21/07/2011	07:30:56	NB 08794 34396	108794	934396		House at shoreline, no discharge pipes apparent
75	21/07/2011	07:33:28	NB 08834 34380	108834	934380		Land drain, wet but not actively flowing
76	21/07/2011	07:34:48	NB 08866 34368	108866	934368		Land drain. 10 sheep with access to shore
77	21/07/2011	07:36:58	NB 08903 34366	108903	934366		Very small stream, not measured or sampled
78	21/07/2011	07:38:38	NB 08936 34382	108936	934382		Mussel barges anchored off shore, 5 sheep visible on opposite shore with approx. 20 more visible on hills above
79	21/07/2011	07:46:32	NB 09049 34398	109049	934398	Figure 12	10 small boats on moorings
80	21/07/2011	07:50:35	NB 09079 34395	109079	934395		Septic tank outlet, not flowing

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
81	21/07/2011	08:00:20	NB 09124 34385	109124	934385		Miaviag pier, 16 small boats and 3 larger fishing boats (all under 15m). Diesel sheen and odour on water. Approx 8 empty moorings. Salmon site office, tourist boat operator shed. Water sample LRMW17 at slipway
82	21/07/2011	08:03:18	NB 09047 34384	109047	934384		Surface drain
83	21/07/2011	08:05:34	NB 08943 34312	108943	934312		Building with septic tank draining to land. 7 sheep on hill above road
84	21/07/2011	08:11:30	NB 08796 34361	108796	934361		Surface water culvert
85	21/07/2011	08:21:35	NB 08699 34812	108699	934812		Septic tank vent adjacent to house
86	21/07/2011	08:50:02	NB 09085 34588	109085	934588		Stream: 20 cm x 3 cm, flow 0.244 m/s, SD 0.002. Water sample LRMW18
87	21/07/2011	08:56:32	NB 09629 34643	109629	934643		2 houses
88	21/07/2011	08:59:38	NB 10027 34641	110027	934641		Drainage from lake, only seeping at the time. Not measured or sampled
89	21/07/2011	09:00:34	NB 10058 34625	110058	934625		Photo of Miavaig mussel lines from vantage point on hills to north
90	21/07/2011	09:33:41	NB 10183 32352	110183	932352		Burn, Abhainn Mhòr a' Ghlinne Ruaidh, west bank
91	21/07/2011	09:34:07	NB 10188 32353	110188	932353		Burn, east bank. Water sample LRMW19
92	21/07/2011	09:37:49	NB 10185 32350	110185	932350		Burn, west bank
93	21/07/2011	09:38:26	NB 10189 32352	110189	932352	Figure 13	Burn, east bank. Point 1: 27 cm deep, flow 0.213 m/s, SD 0.014 Point 2: 26 cm deep, flow 0.202 m/s, SD 0.006
94	21/07/2011	09:43:32	NB 10183 32351	110183	932351		Burn, west bank
95	21/07/2011	09:43:51	NB 10188 32352	110188	932352		Burn, east bank
96	21/07/2011	09:51:13	NB 10171 32570	110171	932570		Hoof prints and sheep droppings on bank. Tidal at this point
97	21/07/2011	09:59:43	NB 10159 32771	110159	932771	Figure 14	4 pipes draining to shore, none actively flowing, all appear to be septic pipes. Some green algae present
98	21/07/2011	10:03:24	NB 10157 32796	110157	932796		Ground seepage. 9 sheep
99	21/07/2011	10:06:03	NB 10160 32844	110160	932844		12 geese
100	21/07/2011	10:09:38	NB 10163 32893	110163	932893		6 sheep
101	21/07/2011	10:20:48	NB 10105 33085	110105	933085		Very small stream, not measured or sampled
102	21/07/2011	10:22:07	NB 10094 33103	110094	933103		Stone groin, small open boat on mooring, boat shed
103	21/07/2011	10:33:15	NB 10008 33241	110008	933241		7 sheep in fenced field adjacent to shore
104	21/07/2011	10:36:46	NB 09965 33295	109965	933295		Bits of rusted iron, glass and broken pottery on shore
105	21/07/2011	10:38:34	NB 09939 33312	109939	933312		Unintentional record – no observation
106	21/07/2011	10:40:35	NB 09938 33313	109938	933313	Figure 15	Cast iron discharge pipe with trickling land drainage adjacent. Pipe broken in places. Seawater sample LRMW20 (180ml) and LRMW21 (30 ml). Carpet of green algae
107	21/07/2011	10:49:02	NB 09863 33375	109863	933375		Adjacent septic tanks (2) above shore, 2 pipes - 1 ceramic pipe runs to tide line, not flowing. 1 plastic pipe to top of bank, dripping
108	21/07/2011	10:58:42	NB 09749 33398	109749	933398		Water seeping from land
109	21/07/2011	11:02:53	NB 09702 33385	109702	933385	Figure 16	Septic tank above shore, 12 sheep, no pipe or odour detected
110	21/07/2011	11:08:55	NB 09637 33387	109637	933387		Small land drain

No.	Date	Time (GMT)	NGR	East	North	Associated photograph	Description
111	21/07/2011	11:17:02	NB 09547 33385	109547	933385	Figure 17	Abhainn Uasaig, pools at base of road, trickles through rocks to loch on opposite side of road. Sheep pens, 6 sheep, 9 sheep further up hill. Septic pipe dripping into pool
112	21/07/2011	11:22:58	NB 09552 33396	109552	933396		Seawater sample, loch side of road. LRMW22
113	21/07/2011	11:26:18	NB 09619 33359	109619	933359		House
114	21/07/2011	11:27:44	NB 09699 33354	109699	933354		House
115	21/07/2011	11:28:16	NB 09729 33355	109729	933355		House
116	21/07/2011	11:29:31	NB 09817 33358	109817	933358		House
117	21/07/2011	11:31:11	NB 09893 33266	109893	933266		House
118	21/07/2011	11:31:44	NB 09909 33231	109909	933231		House
119	21/07/2011	11:32:30	NB 09934 33182	109934	933182		Houses plus 14 sheep up hill away from stream
120	21/07/2011	11:33:46	NB 09952 33135	109952	933135		House
121	21/07/2011	11:35:34	NB 09993 33049	109993	933049		house
122	21/07/2011	11:35:56	NB 10004 33025	110004	933025		house
123	21/07/2011	11:37:13	NB 10033 32964	110033	932964		house plus 9 sheep
124	21/07/2011	11:38:27	NB 10055 32908	110055	932908		house
125	21/07/2011	11:40:24	NB 10088 32768	110088	932768		house
126	21/07/2011	11:40:50	NB 10097 32741	110097	932741		septic tank near house, west side of road. East side of road - farm storage/animal housing
127	21/07/2011	11:45:21	NB 10144 32477	110144	932477		31 sheep east of burn
128	21/07/2011	11:48:07	NB 10163 32374	110163	932374		Hole in road, eroded underneath
129	21/07/2011	11:49:49	NB 10180 32331	110180	932331		17 sheep east of burn
130	21/07/2011	11:50:27	NB 10180 32319	110180	932319		4 sheep west of burn
	21/07/2011	11:51:18	NB 10195 32269	110195	932269		house west plus 18 sheep east of burn
	21/07/2011	11:53:21	NB 10229 32155	110229	932155		2 houses

Photographs referenced in the table can be found attached as Figures 4-17.

Sampling

Water and shellfish samples were collected at sites marked on the map. Samples were transferred to either Biotherm 25 or Biotherm 10 boxes with ice packs and shipped to Glasgow Scientific Services on the day collected for *E. coli* analysis. In all cases, samples were received and analysed on the day following collection. Sample temperatures on arrival ranged between 6.2 and 9.4 C, with samples taken on 19 July arriving above the recommended temperature range of 2-8C. Investigations undertaken by the National Reference Laboratory (NRL) have shown no significant effect on sample *E. coli* concentrations with up to 48 hours' storage at temperatures <10°C. Sample results have been included in Tables 3 and 4.

Seawater samples were tested for salinity by the laboratory and results reported in mg Cloride per litre. These results have been converted to parts per thousand (ppt), and are shown in Table 3.

Salinity and temperature were recorded at the surface, 1 meter, 3 meters and 5 meters depth at a single location using a YSI ProPlus CT probe. The resulting profile is reported in Table 5.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	18/7/2011	LRMW1	NB 1130 3444	Freshwater	3600	
2	18/7/2011	LRMW2	NB 1112 3441	Freshwater	90000	
3	18/7/2011	LRMW3	NB 1083 3449	Freshwater	3800	
4	18/7/2011	LRMW4	NB 1068 3437	Seawater	41	36.0
5	18/7/2011	LRMW5	NB 1067 3438	Freshwater	7200	
6	18/7/2011	LRMW6	NB 1031 3447	Freshwater	500	
7	18/7/2011	LRMW7	NB 0963 3457	Freshwater	500	
8	18/7/2011	LRMW8	NB 0964 3453	Freshwater	800	
9	18/7/2011	LRMW9	NB 0962 3409	Seawater	900	33.4
10	18/7/2011	LRMW10	NB 0941 3432	Seawater	1400	32.5
11	18/7/2011	LRMW11	NB 0929 3440	Freshwater	40000	
12	19/7/2011	LRMW12	NB 0993 3439	Seawater	2	36.2
13	21/7/2011	LRMW13	NB 0960 3687	Seawater	58	37.4
14	21/7/2011	LRMW14	NB 0873 3486	Freshwater	<100	
15	21/7/2011	LRMW15	NB 0381 3461	Freshwater	300	
16	21/7/2011	LRMW16	NB 0874 3440	Freshwater	100	
17	21/7/2011	LRMW17	NB 0912 3439	Seawater	63	34.3
18	21/7/2011	LRMW18	NB 0908 3457	Freshwater	300	
19	21/7/2011	LRMW19	NB 1018 3235	Freshwater	100	
20	21/7/2011	LRMW20	NB 0994 3331	Seawater	400	31.8
21	21/7/2011	LRMW21	NB 0994 3331	Freshwater	700	
22	21/7/2011	LRMW22	NB 0955 3340	Seawater	100	33.4

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	19/07/2011	LRMIAV1	NB 0993 3439	Mussel (rope)	<20
2	21/07/2011	LRMIAV2	NB 0874 3477	Mussel (shore)	<20

Table 5. Salinity profiles

Profile	Date and time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	19/07/2011 10:14	NB 0985 3446	0	35.5	13.6
			1	35.6	13.6
			3	35.6	13.6
			5	35.6	13.60

Water and shellfish sampling locations are shown mapped in Figure 3.

Contamination levels in freshwater ranged from 100 to 90000, with all samples containing >1000 E. coli/100 ml coming from sources along the north shore. Seawater samples were generally less contaminated, though the most contaminated seawater samples were also taken from within Loch Miavaig or along the northern shore of the fishery.

Shellfish samples taken during the survey contained no to very low concentrations of *E. coli.*

Figure 3. Sample results

Photographs

Figure 4. Dry end of discharge pipe

Figure 5. Septic tank above shoreline

Figure 6. End of mussel line from shore

Figure 7. Stream on west side of Uigean

Figure 8. Ceramic septic pipe

Figure 9. Septic discharge from church at Loch Miavaig

Figure 10. Septic tank with dry overflow above shoreline

Figure 11. Iron discharge pipe below house

Figure 12. Boats on moorings

Figure 13. Abhainn Mhor a' Ghlinne Ruaidh

Figure 14. Four discharge pipes

Figure 15. Cast iron discharge pipe

Figure 16. Septic tank and sheep above shore

Figure 17. Discharge pipe to ponded end of Abhainn Uasaig